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VARIETAL AND REGIONAL VARIATION IN PROPERTIES OF WHEAT STARCHES[1]

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Recent investigations have demonstrated variability in the properties of wheat starches. Very little information, however, is available as to the cause of these variations.

Rask and Alsberg (1924) noted differences in the viscosity of pastes made from the starch of different wheats. Mangels (1926), Hermano and Rask (1924), and Malloch (1929) have shown that wheat starches from different sources vary in their susceptibility or resistance to diastase.

More recently Mangels and Bailey (1933a) have shown that starches from different types of wheat will vary in viscosity when treated with cold gelatinizing agents. Mangels (1934) has also shown that starches from different types of wheat will vary in swelling capacity after exposure to heat.

The present study is an inquiry into the causal factors in variation, such as variety (heredity), and environment. The properties of starches have been measured by determining viscosity after treatment with cold gelatinizing agents.

Experimental

Pure starches were prepared from wheats of known variety and cultural history. From the 1932 crop nine samples of flour, representing three varieties (Marquis, Ceres, and Reward) and three locations (Fargo, Edgeley, and Dickinson), were used in preparing pure starches.

There was also available for study small quantities of pure starches prepared from eight varieties of the 1928 crop. Three of the 1928 crop starches were from durum varieties; all other starches were from common wheats.

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Table I gives the phosphorus and nitrogen content of the 17 starches used. There is no significant difference in average nitrogen content of the starches from the 1928 and 1932 crops. The nitrogen content of the starches is due at least in part to contamination by wheat gluten. The data in Table I indicate that the degree of purification was practically the same for both years. There is some varietal variation. The Reward starches are lower in nitrogen content than the starches of the varieties Marquis or Ceres. The low nitrogen content of Reward starches is probably due to the fact that these starches are more easily freed from contaminating gluten than is the case with Marquis or Ceres starches.

TABLE I

PHOSPHOROUS AND NITROGEN CONTENT OF STARCHES

(All analyses on dry basis)

Lab. No.	Variety	Wheat grown at	Per cent P	Per cent N
		1928 Crop		
28–5–6	Marquis	Fargo	0.063	0.045
72	Ceres	Fargo	0.056	0.055
4	Kota	Fargo	0.056	0.044
10	Preston	Fargo & Dickinson	0.053	0.043
12	Progress	Fargo & Dickinson	0.054	0.043
66	Mindum	Fargo	0.059	0.044
68	Kubanka	Fargo	0.059	0.044
70	Pentad	Fargo	0.060	0.045
		Average 1928 Crop	0.058	0.045
		1932 Crop		
33–10–26	Marquis	Fargo	0.075	0.050
29	"	Edgeley	0.081	0.045
32	"	Dickinson	0.075	0.045
27	Ceres	Fargo	0.079	0.045
30	"	Edgeley	0.072	0.043
33	"	Dickinson	0.072	0.048
28	Reward	Fargo	0.064	0.040
31	"	Edgeley	0.059	0.040
34	"	Dickinson	0.075	0.040
		Average 1932 Crop	0.072	0.044

The phosphorus content of the 1928 starches averaged 0.058% as compared with 0.072% for the 1932 starches. This difference in phosphorous content can probably be attributed to differences in seasonal conditions. The 1928 crop was produced in a season of fairly normal temperature and rainfall, while the 1932 season was hot and dry, with soil moisture relatively low. Furthermore, the 1932 season was immediately preceded by three exceedingly hot, dry years.

The phosphorus content of the three durum starches from the 1928 crop is not significantly different from that of the common wheat starches. Marquis starches had the highest phosphorus content for the common wheat starches in 1928, while the starches of the varieties Preston and Progress had the lowest phosphorus content.

For the 1932 crop, Marquis starches averaged higher in phosphorous content than did the Ceres or Reward starches. The difference, however, is not consistent. Regionally, there is no consistent variation in phosphorous content.

Viscosity Studies on Starches

The technique used in the viscosity studies is that described by Mangels and Bailey (1933). Viscosity was determined by means of a special Ostwald pipette. Readings were made at 30° C. and the viscosity is reported as t/tw where t is time of flow for the starch preparation and tw is the time of flow for distilled water. The gelatinizing or swelling agents used were 0.10 molar NaOH, 1.25 molar KCNS, 0.7 molar sodium salicylate, and 4.5 molar urea.

Viscosity of 1928 Crop Starches

Table II records and Figure 1 illustrates the viscosity values for the 1928 crop starches when treated with 0.10 molar NaOH. It will be noted that these eight starches are divided into two distinct classes—starches from common and from durum varieties. The variation in viscosity between the durum varieties is relatively large when compared

TABLE II

VARIETAL VARIATION IN WHEAT STARCHES—1928 CROP

Viscosity with 0.10 Molar NaOH

Lab. No.	Variety	Viscosity t/w					
		0 hr.	1 hr.	3 hrs.	6 hrs.	9 hrs.	24 hrs.
28–5–6	Marquis	1.1	1.9	3.1	3.7	—	5.3
72	Ceres	1.1	2.7	4.3	5.4	—	7.2
4	Kota	1.1	2.3	5.0	6.9	—	10.2
10	Preston	1.1	1.6	2.3	2.9	—	4.6
12	Progress	1.1	1.3	1.9	2.4	—	3.8
66	Mindum	1.1	17.3	28.2	33.6	34.4	37.4
68	Kubanka	1.1	12.5	19.2	22.2	22.7	22.9
70	Pentad	1.2	86.3	106.2	101.9	100.2	91.7

with the variation in viscosity of the common wheat starches. The Pentad starch shows an extremely high viscosity with 0.1 molar NaOH while Mindum starches have a greater viscosity than Kubanka starches.

The common wheat starches show less variation in viscosity. Kota and Ceres starches show a greater viscosity with 0.1 molar NaOH than

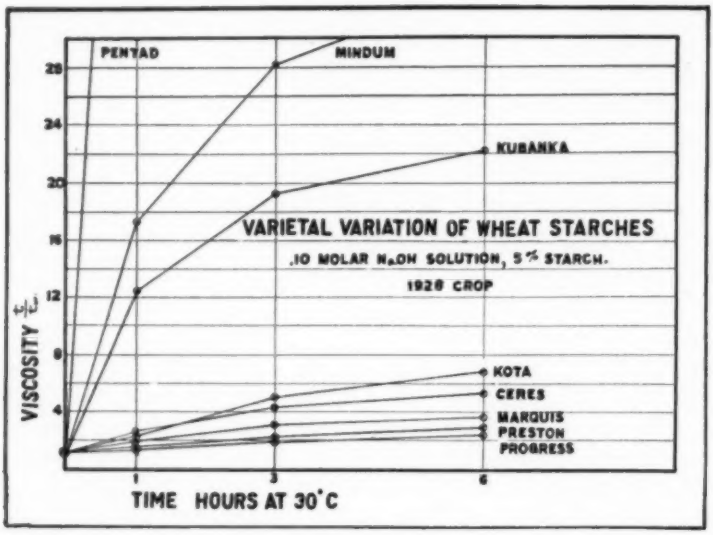

Fig. 1.

do Marquis starches, while the Preston and Progress starches are lower in viscosity than Marquis starches. The position of Preston and Progress is interesting. These two varieties produce flour decidedly inferior in baking quality as compared with the other three common wheat varieties. Preston and Progress also showed a lower phosphorous content (Table I) than the other three varieties.

When 1.25 Normal KCNS was used as a swelling agent the viscosity relationship of these eight starches was quite different. These data are shown in Table III. While the durum starches show a higher viscosity than the common wheat starches, the difference is not as great as was the case with 0.10 molar NaOH. It is also interesting to note that the

TABLE III

VARIETAL VARIATION IN WHEAT STARCHES—1928 CROP

Viscosity with 1.25 Molar KCNS

Lab. No.	Variety	Viscosity t/tw				
		0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
28–5–6	Marquis	1.0	9.1	14.4	18.4	33.4
72	Ceres	1.1	18.7	29.2	36.9	59.4
4	Kota	1.1	15.7	26.1	38.0	58.0
10	Preston	1.1	17.2	27.8	38.0	64.0
12	Progress	1.0	15.5	25.5	33.2	34.8
66	Mindum	1.4	20.9	35.0	44.4	76.5
68	Kubanka	1.4	21.7	39.2	52.5	97.3
70	Pentad	1.8	18.2	32.8	38.8	69.2

ranking of the three durum starches as to swelling capacity is the reverse of that found with 0.1 molar NaOH. In this case the ranking is, Kubanka, Mindum, Pentad, while with 0.1 molar NaOH the ranking was Pentad, Mindum, Kubanka.

The common wheat starches also show a different ranking. Marquis starch in this case is distinctly lower in swelling capacity, while the other four starches are similar (up to six hours). Mangels and Bailey (1933a) have observed that the swelling of starch with KCNS and NaOH solutions are rather different processes.

Viscosity of 1932 Crop Starches

The nine starches of the 1932 crop were obtained from the varieties Marquis, Ceres, and Reward grown at Fargo, Edgeley, and Dickinson. Three rather different environments were represented by these samples. The year 1932 was hot and dry during most of the growing season. While Fargo, in the Red River Valley, usually has a more moderate summer temperature and more rainfall than Edgeley or Dickinson, in 1932 Fargo had less rainfall and higher daily temperature than either Edgeley or Dickinson. The soil at Fargo is a heavy clay; the soils in the Edgeley and Dickinson areas are much lighter.

Viscosity with 0.10 Molar NaOH

In Table IV and in Figures 2 and 3 are shown the viscosity data for the 1932 crop starches when treated with 0.10 molar NaOH. For the

TABLE IV

REGIONAL AND VARIETAL VARIATION IN WHEAT STARCHES—1932 CROP

Viscosity with 0.10 Molar NaOH

Variety	Location	Viscosity t/tw				
		0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
Marquis	Fargo	1.0	1.2	1.5	1.6	2.1
"	Edgeley	1.0	1.2	1.4	1.5	1.8
"	Dickinson	1.0	1.1	1.3	1.4	1.7
Ceres	Fargo	1.0	1.7	2.6	3.1	4.4
"	Edgeley	1.0	1.3	1.6	1.8	2.2
"	Dickinson	1.0	1.2	1.6	2.0	2.7
Reward	Fargo	1.0	1.8	4.0	5.9	11.5
"	Edgeley	1.0	1.4	2.2	3.2	5.7
"	Dickinson	1.0	1.2	2.0	2.8	6.3
Varietal Average						
Marquis		1.0	1.2	1.4	1.5	1.9
Ceres		1.0	1.4	1.9	2.3	3.1
Reward		1.0	1.5	2.7	4.0	7.8
Regional Average						
	Fargo	1.0	1.6	2.7	3.5	6.0
	Edgeley	1.0	1.3	1.7	2.2	3.2
	Dickinson	1.0	1.2	1.6	2.1	3.6

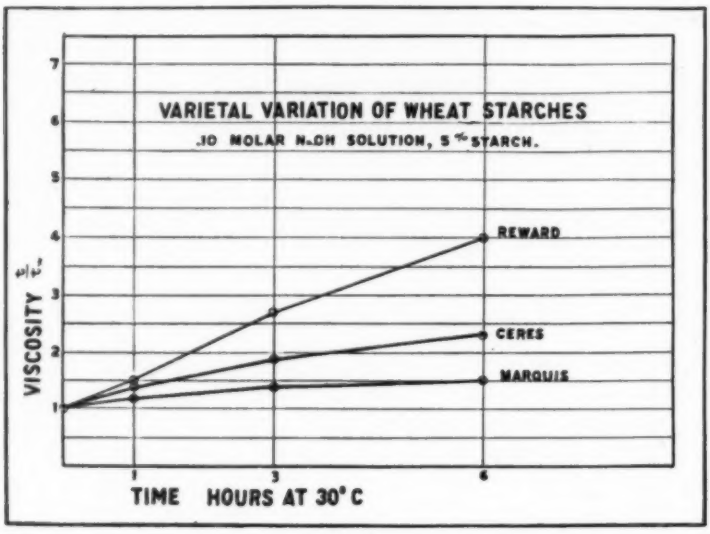

Fig. 2.

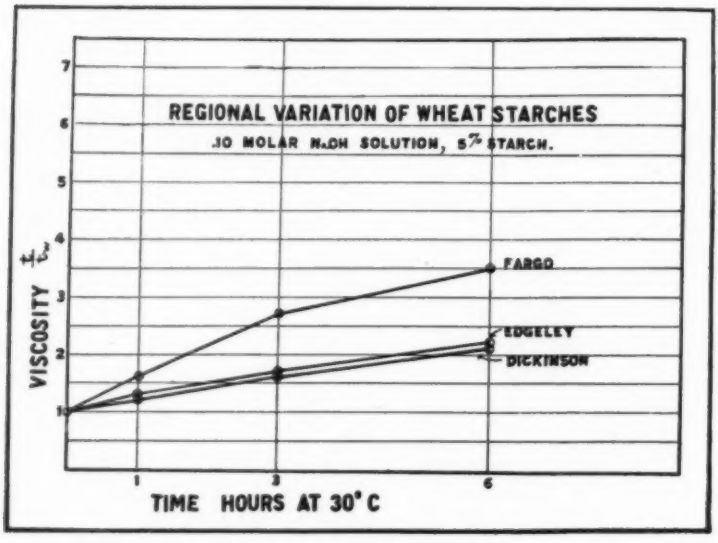

Fig. 3.

three varieties, Marquis starches average the lowest, Reward starches the highest. The viscosities of Ceres starches resemble Marquis starches rather than Reward starches. This relationship for the three varieties is consistent for all three locations.

The starches from wheat grown at Fargo show the highest average swelling capacity with 0.1 molar NaOH. Starches from wheat grown

at Edgeley and Dickinson are quite similar in swelling capacity. The Marquis starches show the least variation due to region in swelling capacity, while the Reward starches show the greatest variation. Differences due to region are not as consistent as varietal variation but with one exception—the starches from the Dickinson wheats show the lowest viscosity.

Viscosity with 1.25 Molar KCNS

The viscosity data obtained with 1.25 molar KCNS are shown in Table V and Figures 4 and 5. The varietal relationship is the same as with 0.1 molar NaOH. Reward starches consistently exhibit the greatest swelling capacity and Marquis starches the lowest swelling capacity.

TABLE V

REGIONAL AND VARIETAL VARIATION IN WHEAT STARCHES—1932 CROP

Viscosity with 1.25 Molar KCNS

Variety	Location	Viscosity t/tw				
		0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
Marquis	Fargo	1.0	3.2	4.8	6.2	11.4
"	Edgeley	1.1	6.0	11.6	16.6	5.9
"	Dickinson	1.1	3.2	5.6	7.7	10.3
Ceres	Fargo	1.1	5.1	8.1	11.5	13.5
"	Edgeley	1.1	10.4	18.7	17.1	3.6
"	Dickinson	1.1	4.0	6.5	9.0	17.5
Reward	Fargo	1.1	11.3	20.7	28.7	21.2
"	Edgeley	1.1	11.3	21.5	27.5	6.5
"	Dickinson	1.1	5.2	9.0	13.5	25.2
Varietal Average						
Marquis		1.1	4.1	7.3	10.2	9.2
Ceres		1.1	6.5	11.1	12.7	11.5
Reward		1.1	9.3	17.1	23.2	17.6
Regional Average						
	Fargo	1.1	6.5	11.2	15.5	15.4
	Edgeley	1.1	9.2	17.3	20.6	5.3
	Dickinson	1.1	4.1	7.0	10.1	17.7

Ceres starches are higher in viscosity than Marquis starches; however, they resemble Marquis starches rather than Reward starches. This relationship is consistent for the three locations.

Regional relationships, however, are different, and are not consistent for the three varieties. Starches from Edgeley wheats show the greatest average swelling capacity, and starches from Dickinson the least, with Fargo starches intermediate (Figure 5). With one exception the starches from Edgeley wheats are consistently high in viscosity. Reward starches from Fargo show a swelling capacity similar to the Edge-

ley wheats, with the viscosity of the Dickinson starches much lower. With Marquis and Ceres varieties, however, the starches from Fargo and Dickinson wheats are similar, while the Edgeley starches show a much higher viscosity. These variations would indicate that Reward

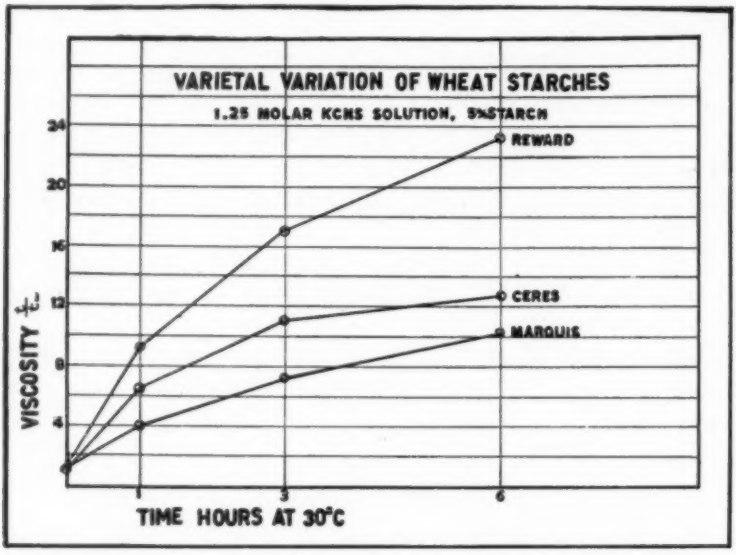

Fig. 4.

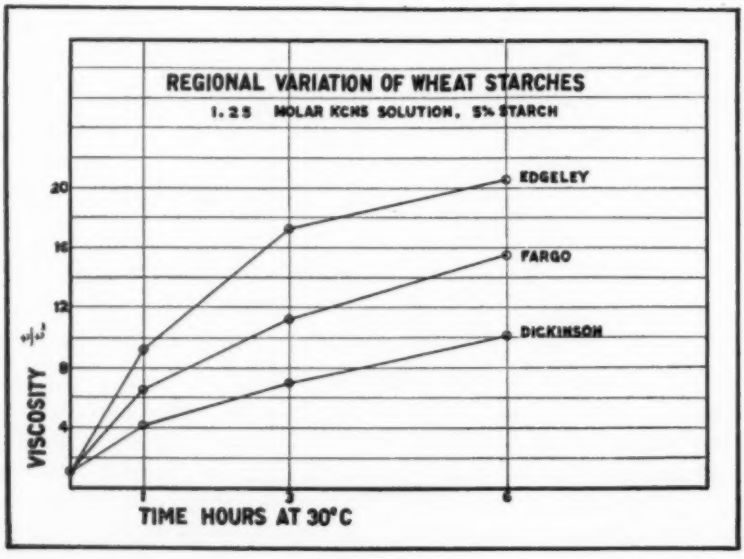

Fig. 5.

reacts differently to environment than Marquis or Ceres when starches are being elaborated.

Viscosity with 0.7 Molar Sodium Salicylate

The viscosity data obtained using 0.7 molar sodium salicylate are shown in Table VI and Figures 6 and 7. The three varieties show the

TABLE VI

REGIONAL AND VARIETAL VARIATION IN WHEAT STARCHES—1932 CROP

Viscosity with 0.70 Molar Sodium Salicylate

Variety	Location	Viscosity t/tw				
		0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
Marquis	Fargo	1.2	3.5	9.2	13.6	23.1
"	Edgeley	1.2	3.9	11.2	16.7	32.7
"	Dickinson	1.2	2.8	7.5	11.6	22.9
Ceres	Fargo	1.2	6.6	14.8	20.6	37.2
"	Edgeley	1.2	5.7	16.4	24.9	46.9
"	Dickinson	1.2	3.7	10.3	14.9	31.2
Reward	Fargo	1.2	11.5	24.6	33.9	74.4
"	Edgeley	1.2	6.1	16.9	25.8	56.7
"	Dickinson	1.2	4.5	12.4	17.9	37.9
Varietal Average						
Marquis		1.2	3.4	9.3	14.0	26.2
Ceres		1.2	5.3	13.8	20.1	38.4
Reward		1.2	7.4	18.0	25.9	56.3
Regional Average						
	Fargo	1.2	7.2	16.2	22.7	44.9
	Edgeley	1.2	5.2	14.8	22.5	45.4
	Dickinson	1.2	3.7	10.1	14.8	30.7

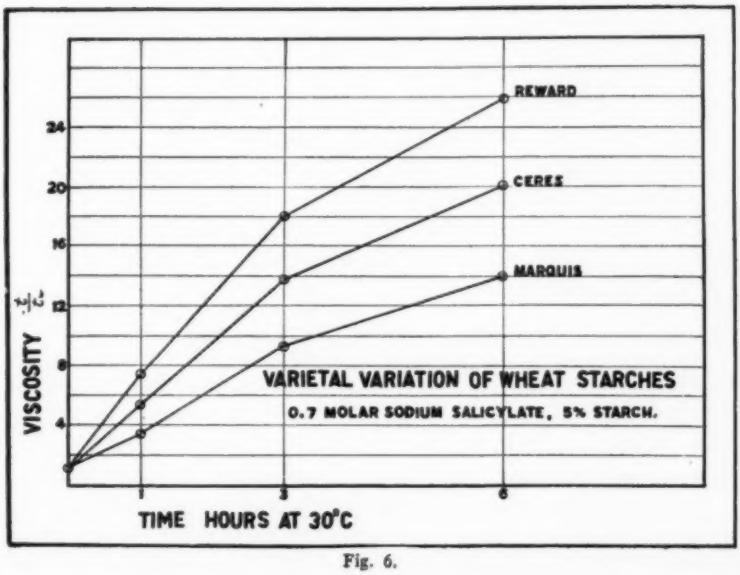

Fig. 6.

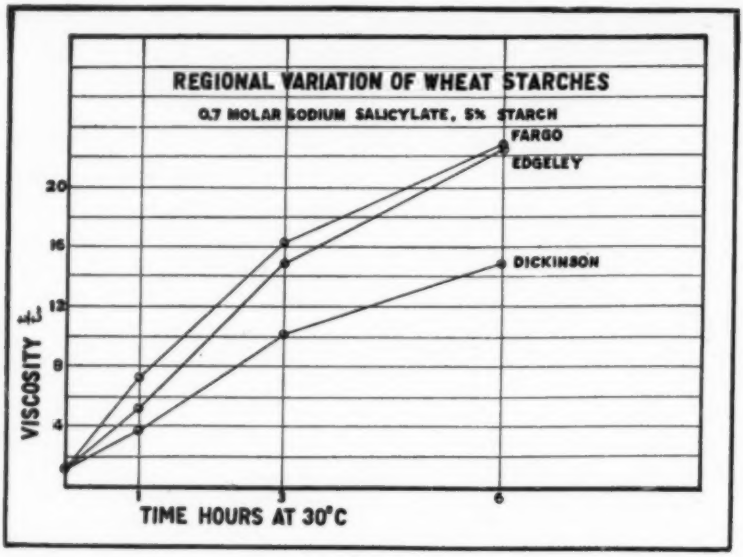

Fig. 7.

same relationship as in the case of 0.1 molar NaOH and 1.25 molar KCNS with Reward starches high in viscosity and Marquis starches low. Ceres starches, however, in this case are intermediate between Reward and Marquis starches, and do not resemble Marquis starches as in the other two cases. Marquis starches again are consistently low in swelling capacity and Reward starches consistently high.

Regional variation shows a different relationship than with the other two reagents. The starches from Fargo and Edgeley wheats are similar in swelling capacity, while Dickinson wheat starches average much lower in viscosity. Marquis and Ceres starches show relatively less variation in swelling capacity due to region than Reward starches. In case of Reward starch the Fargo sample exceeds Edgeley in swelling capacity, but with Marquis starch, Edgeley grown varieties exceed Fargo grown varieties in viscosity. With Ceres starches the difference in viscosity between Fargo grown and Edgeley grown varieties is small. The swelling capacity of starch from the Dickinson grown wheats, however, is consistently low.

Viscosity with 4.5 Molar Urea

Table VII and Figures 8 and 9 show viscosity data obtained with 4.5 molar urea. The same variety relationship as with other reagents is noted. Ceres starch in this case, however, averages nearer to Marquis starch than was the case with the other reagents. Marquis starch consistently shows the lowest viscosity and Reward starch the highest for the three locations.

TABLE VII

REGIONAL AND SEASONAL VARIATION IN WHEAT STARCHES—1932 CROP

Viscosity with 4.5 Molar Urea

Variety	Location	Viscosity t/tw 0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
Marquis	Fargo	1.3	4.2	4.8	5.5	6.6
"	Edgeley	1.2	4.8	6.0	6.7	8.4
"	Dickinson	1.2	4.3	5.1	5.7	7.4
Ceres	Fargo	1.3	5.4	6.5	7.1	9.4
"	Edgeley	1.3	5.7	6.8	7.8	10.1
"	Dickinson	1.2	4.7	5.7	6.2	7.8
Reward	Fargo	1.3	9.3	11.6	13.3	20.5
"	Edgeley	1.3	8.2	10.2	11.8	16.9
"	Dickinson	1.2	6.5	8.0	9.3	12.9
Varietal Average						
Marquis		1.2	4.4	5.3	6.0	7.5
Ceres		1.3	5.3	6.3	7.0	9.1
Reward		1.3	8.0	9.9	11.5	16.8
Regional Average						
	Fargo	1.3	6.3	7.6	8.6	12.2
	Edgeley	1.3	6.2	7.7	8.8	11.8
	Dickinson	1.2	5.2	6.3	8.0	9.4

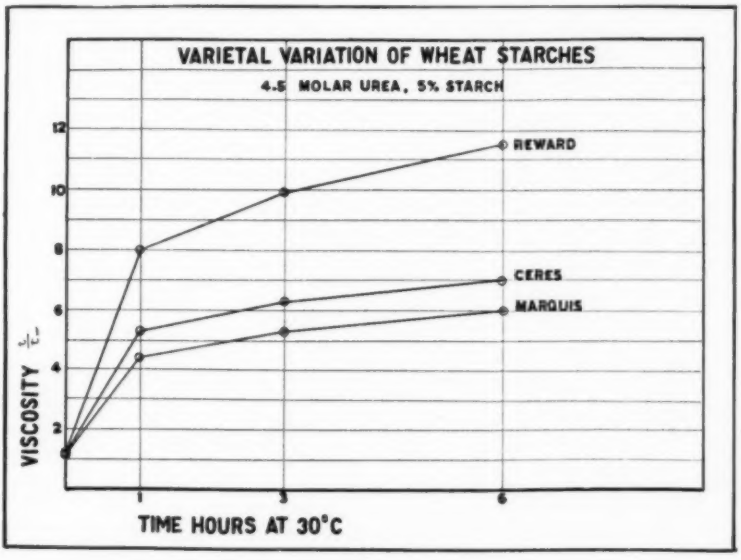

Fig. 8.

The regional variation of viscosity with urea is similar to that found using 0.7 molar sodium salicylate. Starches from Fargo and Edgeley grown wheats show very similar swelling capacities with 4.5 molar urea. Regional variations, however, are smaller than with the other reagents.

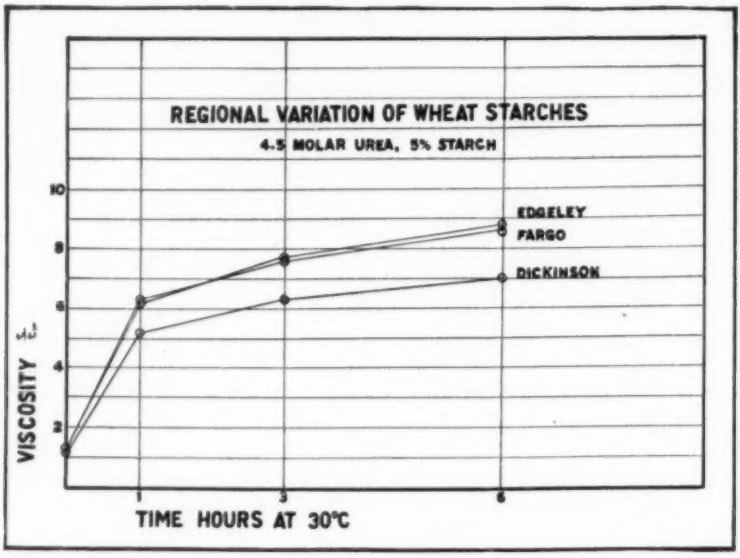

Fig. 9.

Starches from Marquis wheat grown at Dickinson showed a greater swelling capacity than when grown at Fargo. In the case of Reward and Ceres, however, the starch from Dickinson grown wheat was consistently low.

Seasonal Variation

Marquis and Ceres starches from wheat grown at Fargo were available from the 1928 and 1932 crops (see Table I). A comparison of the swelling capacity of these starches with 0.1 molar NaOH and 1.25 molar KCNS is given in Table VIII and Figure 10. The starches from the

TABLE VIII

SEASONAL VARIATION IN WHEAT STARCHES

Viscosity with 0.10 Molar NaOH and 1.25 Molar KCNS

Variety	Crop Year	Viscosity t/tw				
		0 hr.	1 hr.	3 hrs.	6 hrs.	24 hrs.
	0.10 Molar NaOH					
Marquis	1928	1.1	1.9	3.1	3.7	5.3
"	1932	1.0	1.2	1.5	1.6	2.1
Ceres	1928	1.1	2.7	4.3	5.4	7.2
"	1932	1.0	1.7	2.6	3.1	4.4
	1.25 Molar KCNS					
Marquis	1928	1.0	9.1	14.4	18.4	33.4
"	1932	1.0	3.2	4.8	6.2	11.4
Ceres	1928	1.1	18.7	29.2	36.9	59.4
"	1932	1.1	5.1	8.1	11.5	13.5

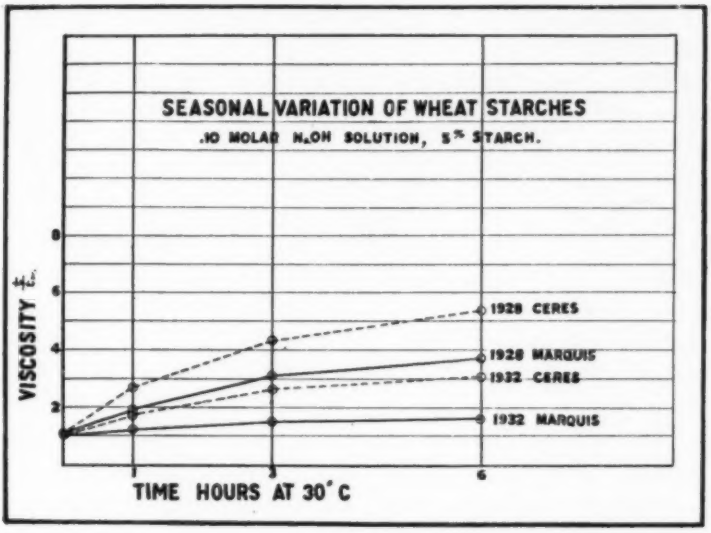

Fig. 10.

1928 crop show a consistently greater swelling capacity than the starches from the 1932 crop. In 1928, July rainfall at Fargo was 7.17 inches while in 1932 it was only 1.36 inches. The average June temperature in 1928 was 60.2° F. as compared with 68.9° F. for 1932. The daily temperature for July 1932 was 72.1° F. as compared with 69.3° F. for July 1928. This would indicate that the swelling capacity of starches elaborated under conditions of drouth and excessive heat is less than when starch is produced under more normal conditions of temperature and rainfall.

Discussion

Mangels and Bailey (1933) from viscosity studies on starches from different types of wheat concluded that chemical or morphological differences in starches which affect viscosity are probably of a complex nature. In the present study, a remarkable consistency is found in the viscosity relationships of starches from the three varieties, Marquis, Ceres, and Reward. The consistent differences between these three varieties would indicate a rather definite varietal or hereditary factor affecting chemical or morphological properties of wheat starches.

The regional variation in starch properties is not consistent, however, when different swelling agents are used. Varietal reaction to change in environment differs, since the Reward starch shows greater variation with change of environment than either Marquis or Ceres starches. The inconsistency of the regional variation in starch properties would indi-

cate that this variation is of complex nature and that several chemical or morphological factors may be involved.

The seasonal variation indicates that starches produced in hot, dry seasons are less susceptible to the action of swelling agents than starches produced under more humid weather conditions. This seasonal variation was entirely consistent with both 0.1 molar NaOH and 1.25 molar KCNS.

Some relationship between phosphorous content and swelling capacity is indicated. The swelling capacity would appear to vary inversely as the phosphorous content. The average viscosity of the starches of the three varieties, Marquis, Ceres, and Reward varies inversely as their average phosphorous content. Marquis and Ceres starches from the 1928 crop show a greater swelling capacity than starches of the same varieties from the 1932 crop; and the phosphorous content in both cases is higher than in the case of 1928 starches. On the other hand, Preston and Progress starches show a low phosphorous content and a relatively low viscosity with 0.1 molar NaOH.

Summary

The phosphorous content of starches from the 1928 crop was lower than that of the starches from the 1932 crop, indicating that seasonal conditions affect this factor. Nitrogen content did not vary significantly for the two years.

Starches from different varieties of common wheat showed consistent variation in viscosity with the four gelatinizing agents used. The order of magnitude of viscosity for these varieties was Reward, Ceres, Marquis.

Regional variation is not consistent, indicating that the cause of variation in this regard is complex in nature, and not due to a single chemical or morphological factor.

Seasonal variation indicates that in hot, dry seasons the wheat plant produces wheat starches less susceptible to action of swelling agents than when the starches are produced in seasons of lower temperature and more abundant rainfall.

An inverse relationship between phosphorous content and swelling capacity or viscosity is indicated.

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SIX YEARS FARINOGRAPHY

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(Read at the Convention, June, 1933)

This paper will concern itself with our experiences covering a period of six years in testing the baking value of flour by mechanical means. In Europe, as you probably know, we have much more difficulty with the baking test as an indicator of flour behaviour than you have in this country. We have many more varieties of wheat to deal with, varieties of wheat coming from all over the world, and we have many different baking methods and different types of bread. Those are, perhaps, the two main reasons why the baking test as a means of determining flour quality has been largely abandoned and why so many attempts have been made to develop methods of flour testing by mechanical means. We have had the Hankoczy-Farinometer, the Chopin-Extensimeter, the Bühler-Comparator, and as the last development the Brabender-Farinograph. While the first three are based on fairly much the same principle, the Farinograph has gone new ways by employing the dynamometer as the measuring instrument and by registering the torque of a given quantity of dough under a continued kneading and stretching abuse. This abuse is carried on until the dough is fully broken down. This is one of the most important features of the Farinograph, *viz.*, that it measures dough-quality and gluten-strength dynamically rather than statically as is the case with all previous devices.

When the Farinograph was first introduced into the United States several years ago, we already had a fairly well developed testing method for European flours. In this country, however, the correlation between the Farinograph indications and practical baking results was less pronounced. This situation gave a lot of trouble, and we have devoted the greater part of the last few years to determine to what this apparent lack of correlation was due. Investigations have led to the conclusion that with European flours the gluten-complex is the most important factor of baking value, and that the gassing power of a flour is a much smaller problem. In the United States the situation seems to be quite reverse. We long ago became convinced that nobody in this country should pay a premium for high protein wheats since there are very few

flours which do not have sufficient gluten-strength. A great deal of trouble has come from the lack of gassing-power. The literature of cereal chemistry research for the last few years shows that the importance of gassing-power as an element of baking value has finally been realized by most cereal chemists. In this connection, I wish especially to refer to the work of Dr. Blish, and particularly to one of his experiments about which he has not published. He is reported to have fermented a medium-strong flour some 48 hours, adding, at certain periods, new doses of sugar to keep the fermentation going and to have made fairly good bread after this long fermentation. This shows better than anything else that in most cases a lack of baking value is not a lack of gluten-strength, but rather a lack of gassing-power.

One must always remember that the baker and the miller look at the question of "baking value" from different points of view, or at least think of the term in a different way. The baker, especially the wholesale baker, with a large commercial plant, looks at the baking quality of flour as a whole. As far as he is concerned, a flour either bakes well or does not bake well. He has a definite schedule set up for his bakeshop, and he wants to buy flours which in their fermentation requirements fill in with this schedule. If he has worked with a certain flour for six weeks without difficulties and then receives a new flour in the seventh week which causes trouble, he is apt to immediately make a strong complaint and very seldom shows any inclination to find out for himself where the trouble lies.

It is, therefore, the first commandment for a miller, that he should know more about flour than the baker and that he should look at the question of flour quality and baking value from a different point of view than does the baker. When the baker complains, it is essential that the miller should be able to find out what is wrong with the flour. A baker's complaint has very often little to do with the baking value of the flour. It may just happen that the flour does not fit in with the baker's schedule. When given to other bakers, this particular flour may produce wonderful results.

"Baking value" is a complex term, and Europeans long ago decided that one must go further and determine singly the various factors making up the "baking value" of a flour. When viewing the baking process as the dough goes from mixer to oven, there are two main factors which are subject to change: first, the gluten-complex; and second, the rate of gas-production to hold and support the gluten-structure in good shape.

Right here is where the shortcomings of test baking come in. The test-bake is a conglomeration of many factors, and if only one of these factors is changed, the result may give us an entirely different

picture. If a test-bake gives us a good loaf, we can only say that the flour would be satisfactory in a commercial way if exactly the same conditions prevailed as those under which the test-bake was conducted; and that brings us the answer to the difficulties of the miller when he tries to determine whether his flours are good or bad. His bakery-customers may number to the hundreds, and each of them employs methods slightly different from the other. In order to keep each one of these customers satisfied, the miller would find it necessary to make a separate baking test for each lot of flour going to different bakers and to vary this baking test in accordance with the variations in baking procedure in the several hundred bakeshops of his customers. As the average baking-test is conducted today, its results are of very little help to the miller.

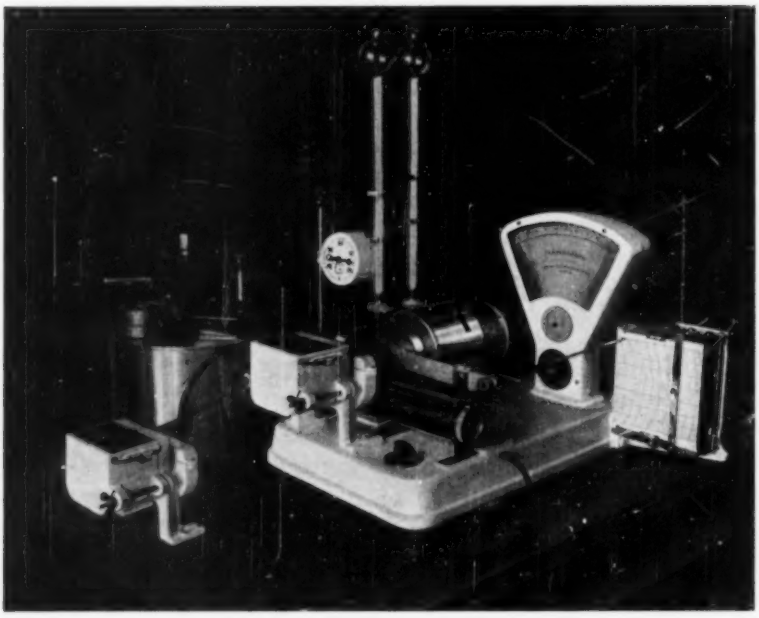

Fig. 1.

Coming back to the all-important separation of gluten and gassing-power, we are using the Farinograph to draw a picture of the gluten properties of a flour. This apparatus is illustrated in Figure 1. You will note that this Farinograph is somewhat changed since the first model introduced in this country several years ago. We have added a thermostat and a larger recording device to the original model. The improvements are mainly due to experiences with the machine in this

country. While European flours are fairly weak on the average, most American flours are rather strong and require three times as long for testing as the European flours. Consequently during this testing process they heat up much more. Extensive trials with American flours convinced us that temperature regulation was necessary. At the same time we provided for temperature regulation of the damper-oil to insure absolutely constant readings all year round.

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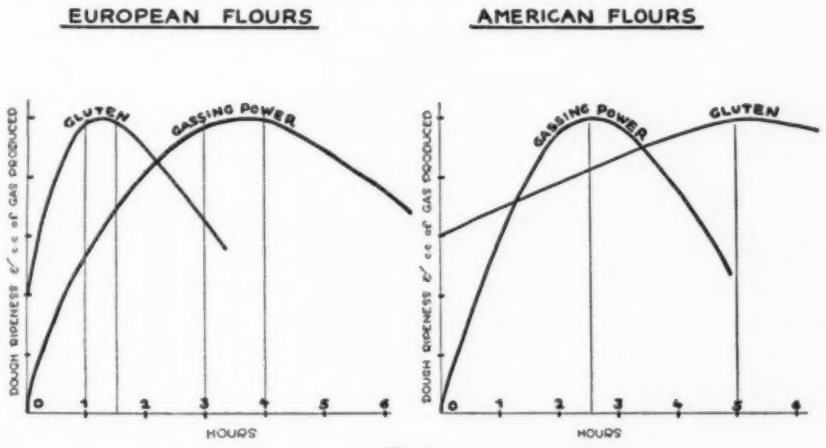

Fig. 2.

In Figure 2 is shown a diagram illustrating the average behaviour and the differences between European and American flours. The abscissa gives the time in hours of fermentation and the ordinate denotes gluten ripeness as well as highest rate of gassing power. The heavy black line shows the physical dough (gluten) development, which, of course, does not start on zero since the dough as it comes out of the mixer has already certain elastic properties. The interrupted line shows the development of the rate of gassing power. The latter, of course, begins at zero after the dough-mixing is completed. In the diagram illustrating the average European flour, the first time of physical dough ripeness is between an hour and an hour and a half. This is especially so in Germany where we have a mixture of 70% domestic soft wheat and 30% hard wheat. Within this 1 to 1½ hours our rate of gas-production is usually not sufficiently developed to give us that balance of gluten-ripeness and gas-production which we need in order to get the optimum results from a specified flour. At the third hour, when sufficient gassing-power has developed, the gluten is usually sadly over-fermented. In Germany, therefore, the most important chemical improvers are those which purport to increase the rate of gas-production

in the early stages of fermentation. This is especially necessary since night-baking is prohibited in Germany and the baker may not enter his shop before five o'clock in the morning. At seven o'clock, however, he has to start delivering his rolls. The roll business is quite important in Germany and a large part of the wheat flour production is used for it.

The diagram illustrating the average American flour is quite different. Here one sees a slow development of the physical (gluten) properties which comes to its best between the fifth and sixth hour. On the other hand, the gassing-power very often comes to its best much earlier and is beyond its best when the first gluten-ripeness is attained. This has been especially so with the low-diastatic flours during the last few years which have caused the frantic search for gassing-power improvers and the introduction of " fermasured," " dia-tized," " fermentation-controlled," etc., flours which are by no means secret flour processes, but have merely a small addition of properly germinated wheat flours. With such additions the gassing-power is prolonged and the ripening of the gluten is slightly shortened (due to the action of the higher amount of proteolytic enzymes which the germinated wheat flour contains), and we are thus getting nearer the balance between best gluten-ripeness and highest rate of gas-production, which is so sorely needed in order to obtain optimum baking results.

The basic importance of this type of diagram cannot be overestimated. It is necessary to get away from speaking about the " baking value " of wheat flours in terms of chemical constituents (protein, maltose, etc.). The baker, whose judgment after all is the final criterion of flour, is primarily concerned with flour quality from the point of

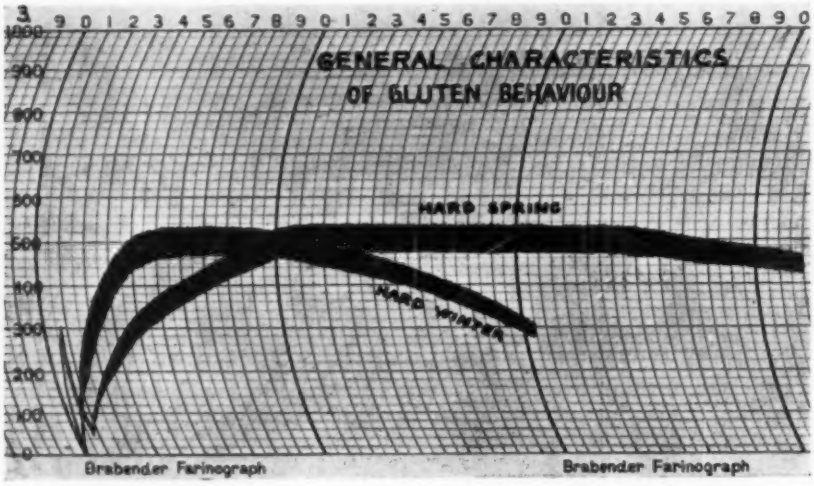

Fig. 3.

view of his own bakeshop rather than the protein and maltose figures. To picture the baking value of flour in the above type of diagram, will bring you much nearer to the baker's way of thinking.

In the next diagrams it is intended to show how one arrives at the basic diagram by means of the Farinograph and the Fermentograph. Figure 3 illustrates the average characteristics of the two most important types of American bread flours—hard spring and hard winter wheat flours. These two curves are made with flour-water doughs only and, of course, show only the gluten behaviour during a period of continued stress, which we have found has a close correlation to the behaviour during fermentation. This diagram excludes the influence of any enzymatic activity which we detect in other tests and which I shall show to you in a later diagram. The hard winter flour develops very quickly in the mixer, whereas the hard spring flour takes a much longer time. We have found that a flour with a fairly short developing time in the Farinograph also needs a shorter time to attain its best gluten-ripeness. A flour which develops in the Farinograph rather slowly has "tough" characteristics and usually tends towards the gluten-bound side. Such flour needs a much longer fermentation time and a more terrific fermentation abuse in order to develop fully.

Fermentation tolerance in this type of curve is shown by the length of time that the curve remains level and also maintains fairly well its width of band. It is at once evident then, that the hard spring flour has a much longer fermentation tolerance than the hard winter flour, which, of course, is borne out by the usual experience. In Europe we do not call this quality "fermentation tolerance" any longer, but merely "stability" which is really more correct. Proper fermentation tolerance is obtained only then when gluten-ripeness and highest rate of gas-production fall together and when this "balance" of the two factors is maintained for a certain length of time. If there is a lack of gas production in a strong flour, we have the case as described in Figure 2 (American flours). There we have a good fermentation tolerance or stability of the gluten, but no fermentation tolerance of the gassing-power.

As I previously stated, the curves given in Figure 3 were made with flour and water alone in order to separate gluten strength from the influence of enzymatic activity. In Figure 4 will be seen the diagram of a test made with a dough containing flour, water, salt, and yeast. Here full play is being given to the action of the enzymes. The test is made in the following way:

The dough is developed to its optimum and the Farinograph then switched off. At hourly intervals, it is switched on again for two min-

utes. The interruptions in the curves, therefore, mean rest-periods of one hour each during which the dough ferments in the Farinograph-mixer under close temperature- and humidity-control (thus using the Farinograph-mixer as a fermentation cabinet). The dough is never touched by hand during the entire process. From this curve we can determine the time of best dough ripeness and also the length of the "physical" fermentation tolerance (stability). As soon as the greatest

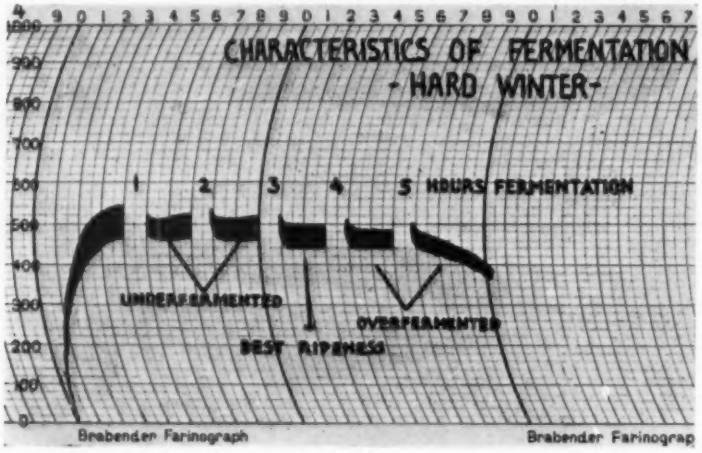

Fig. 4.

width of band is obtained, the dough has reached its highest elastic properties and, therefore, its best ripeness. As soon as the curve begins to turn down, it means that the dough is over-fermented and cannot any longer stand the abuse of mechanical modification. From Figure 4 it will be seen that the best ripeness is attained after the third hour and that the fermentation tolerance or stability is less than one hour, since the curve shows signs of fatigue after the fourth hour of fermentation. In Figure 5, which shows the fermentation curve of a hard spring wheat flour, we see that the best ripeness is attained after four hours, and that the tolerance goes well into the fifth hour. This, of course, is a usual experience with such a strong flour. The importance of this type of curve lies in the fact that you can measure with it the effect of diastatic and particularly proteolytic enzymes on the consistency and the elasticity of the dough during fermentation. Let us take an example which is very acute at the moment.

It is a well-known fact that the uncontrolled addition of germinated (malted) wheat flour is very dangerous and that with a highly germinated flour it often depends on half or even less than half of one percent whether flours will be all right or whether they will be over-treated

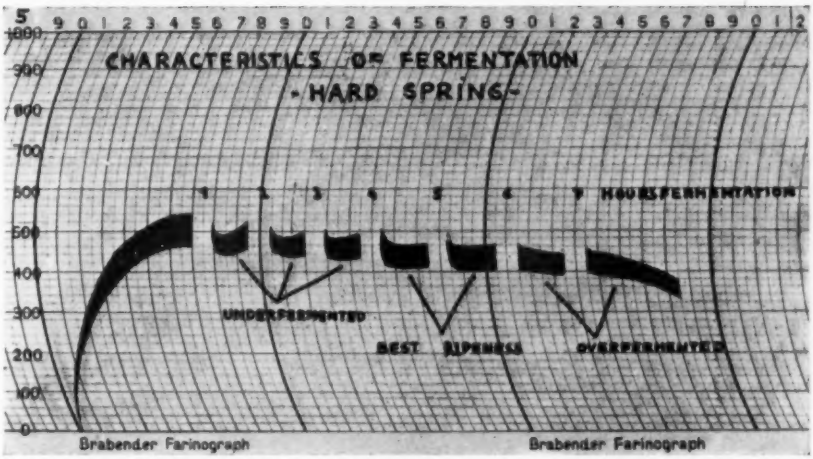

Fig. 5.

and produce " runny " doughs. With this type of curve we can determine exactly the proper additions and see whether with a new delivery of malt flour the amounts should be changed. Of course, the latter type of curve should be made only on special occasions as it takes from five

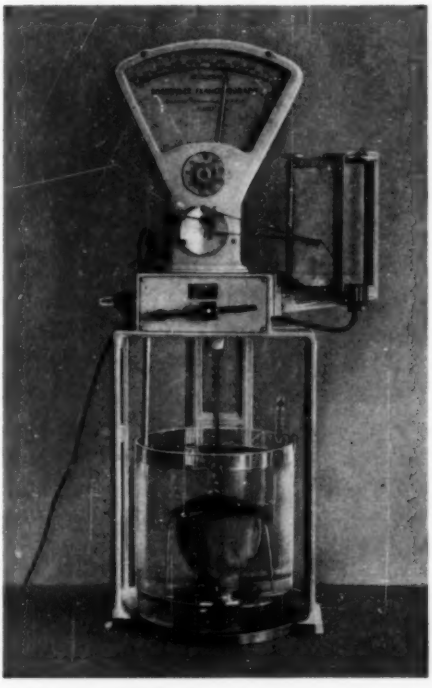

Fig. 6.

to seven hours, whereas the flour-water curves shown in Figure 3, which give you most of the information, take from twenty to thirty minutes only.

The second factor which we have to deal with in the question of "baking value" is the gassing power. We have developed a device called the Fermentograph for measuring the amount of gas-production at each interval of fermentation. This device is shown as Figure 6. Its principle is as follows:

A definite weight of dough (400 gms. mixed to a definite consistency and optimum point of dough development) is put into a rubber bag and the latter is submerged under water. As the carbon-dioxide gas develops in the dough, the bag expands and displaces the water. This displacement is exactly 1 cc. of water (or 1 gram) for every cubic centimeter of CO_2. Thus the exactness of the measurement is very great since water is about five hundred times as heavy as gas. The expansion of the bag and water displacement is equal, of course, to a loss of weight, which is directly transferred into the scale mechanism and also on the diagram where a definite curve is drawn of the amount of gas produced.

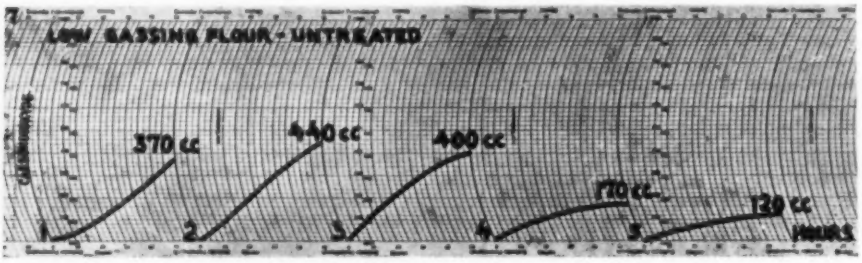

Fig. 7.

Figures 7, 8, 9, and 10 illustrate such gassing-power curves. Figure 7 illustrates an American flour, untreated, of low diastatic activity. Each line represents the amount of gas developed during each hour of fermentation, and the diagram paper is so arranged that this amount can be read off directly in cubic centimeters. Thus during the first hour the amount of gas produced was 370 cc., in the second hour 440 cc., in the third hour 400 cc., in the fourth hour 170 cc., and in the fifth hour 120 cc.

The steeper these lines, the more gas is produced, of course. After each hour of fermentation the rubber bag is taken out of the water bath (which, by the way, has close temperature control) and is then punched without the dough being touched by the human hand, and the gas driven out through a small valve on top of the opening. The apparatus itself

permits of a very fine check as to whether this punching has been done correctly, since the scale pointer and the writing pen will go back to zero if any gas is left in the dough. Of course, to drive out the gas to the last cubic centimeter is impossible. We have, therefore, provided for a sliding weight in front of the scale head to be used as an adjustment of small amounts of gas which were left in the dough.

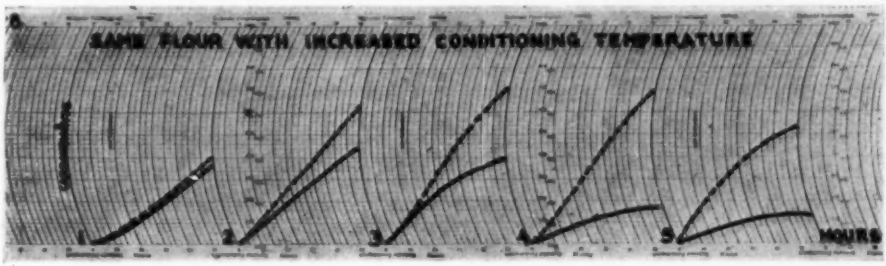

Fig. 8.

Figure 8 shows the same flour again, in the heavy black lines. The interrupted lines show the gassing power of the same flour but with a very definite wheat conditioning ahead of the milling process. This conditioning was done with increased temperature and with a view of increasing the gassing power. The European system of conditioning in large conditioning machines, under the application of heat, provides very good possibilities in this direction. Through the application of heat which may take place several times during the conditioning process, the stage is set for germination to start and enzymatic activity is animated. In this manner, by a comparatively simple and natural process the diastatic activity of the wheat can be improved very easily without the rather expensive addition of ½ to 1% of germinated wheat flour which has to be bought from malting factories and which may lack the desirable quality and uniform diastatic strength. In Europe most every mill works with conditioning plants.

The problem of a lack of diastatic activity is so well understood there that very few millers make separate additions to their flours of special germinated wheat flours bought from malting factories. The problem of the conditioner for America is well worth considering, even if only from the point of view of saving the expense of malted wheat flour.

Figure 9 shows the same untreated flour again in the heavy black lines whereas the interrupted lines show the effect of the addition of ½% malt flour. The effect of this malt is really terrific and it would be the ideal gassing-power booster if it was not for the fact that it is dangerous to use too much malt flour, because it contains not only the

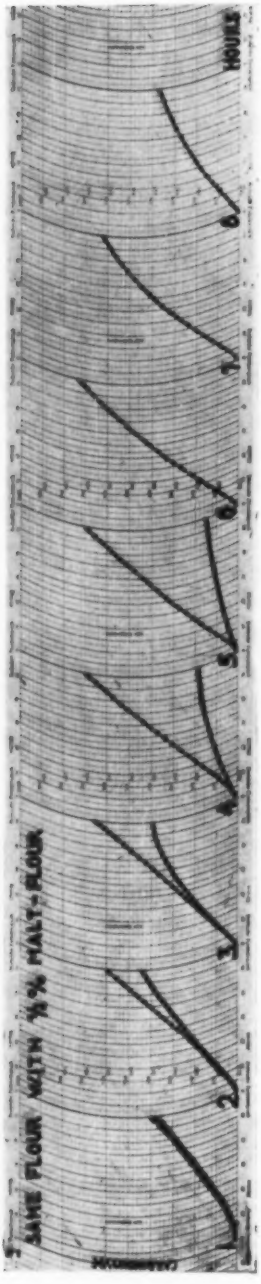
SAME FLOUR WITH 1% MALT-FLOUR
HOURS
1
2
3
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Fig. 9.

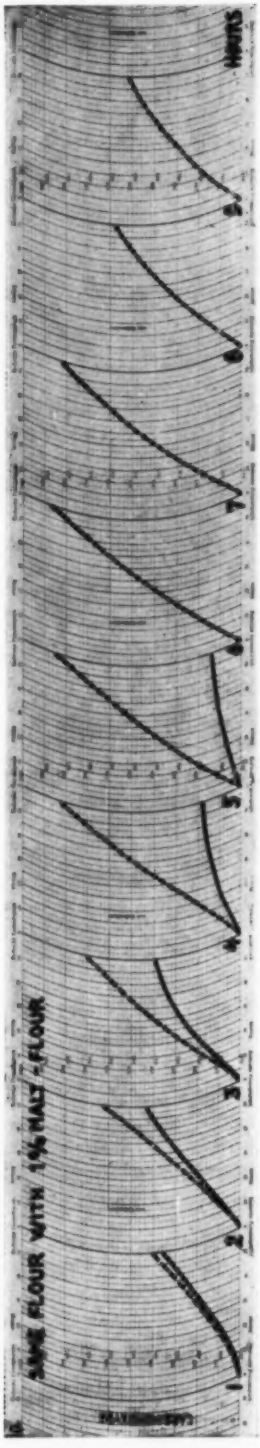
SAME FLOUR WITH 1% MALT-FLOUR
HOURS
1
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Fig. 10.

desirable diastatic enzymes, but also the sometimes undesirable proteolytic enzymes. While the diastatic enzymes attack the starch granules and by stages finally transform them into sugars to serve as yeast food, the proteolytic enzymes on the other hand attack the gluten structure and make it less capable to hold the gas and produce the desirable, well-piled loaf of bread. Therefore, too much of an addition of malt flour will greatly reduce the fermentation tolerance of flours and may do a much greater harm than the increase of the gassing-power could improve.

Furthermore the addition of greater amounts of malt flour does not increase the gassing-power correspondingly, as is evident from Figure 10, where the flour had an addition of 1% malt flour. The gassing-power rate shown in Figure 9 with an addition of ½% malt flour, will ordinarily suffice for the average American baking process. The addition of a larger amount as shown in Figure 10 is, therefore, not only harmful to the gluten structure, as proven in the last paragraph, but is also costly and unnecessary since too great a gassing-power is just as undesirable as one which is too low. Of course, it shall not be said that generally ½% should be used for every flour. The amount of malt flour used depends on the original diastatic power of the flour and also on the requirements placed on it, *i.e.*, the length and conditions of the baking process.

In conclusion I should like to say that it should not necessarily be the aim of a miller to make the best flour, but rather to make a uniform flour and also one that is well balanced between fermentation requirements and highest rate of gassing-power. To make the best and strongest flour is always very expensive. It requires higher wheat prices to be paid and it also entails a great deal of customers complaints and dissatisfaction since to every new flour type you put out, your bakery customers will have to become accustomed. Since the latter are set on one definite baking schedule, they will much more appreciate a uniform flour from delivery to delivery, even if this flour is not one of the strongest obtainable.

Very often a uniform flour will also fetch a higher price. In England we have the example of the Millenium flour milled by Spiller's. This flour is always sold one shilling or almost five per cent higher than any other flour of the same grade. The bakers are glad to pay this price since they can depend on the uniformity of this flour year in and year out.

SOME FACTORS INFLUENCING THE QUALITY OF CAKE FLOURS

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(Presented at the Annual Meeting, June, 1934)

Introduction

Information on what constitutes quality in cake flour is comparatively limited, and it was for this reason that an endeavor was made to obtain some data on the subject. Although the experiments have not been carried out as extensively as we should like, yet the data so far obtained should prove interesting.

Many factors are found to influence the quality of cake flours. The quality and quantity of protein in the wheat used for milling the flour is important. The percentage extraction, or yield of the flour, also affects the cake baking quality. Some maturing and bleaching agents have been found to markedly improve cake flour when used in the proper amounts and incorporated in products suitable for this type of flour. The granulation, or fineness of grind, has also been found to be very important. Other factors of lesser importance are moisture content in relation to keeping properties of the flour, color of the flour as indicated by the slick test, ash content, etc.

Patterson (1924) discussed the importance of fineness of grind, or granulation, on cake flour quality. He stated that "For uniform cake texture, the flour particles should be as nearly identical in size as possible and the ideal seems to require that each individual starch cell be separated from its neighbor, not a practical possibility, but an ideal. Our experience, through daily examining samples under the microscope and routine tests, shows us that the closer we approach this condition, and the finer the chunky or massive particles become, the lighter and of more delicate texture the cake."

Alsberg (1928) points out that wheat starches do not burst and disintegrate when boiled, but the granules merely swell without losing their individuality. He concludes that the physical properties of gelatinized starch depend upon the size.

Katz (1928) points out two grades or orders of gelatinization of starches. In the first order, starch with 50% water added and gela-

tinized at 100° C. for one hour, remains as a white powder but each individual starch granule has increased in size. In the second order of gelatinization, however, that is, in the presence of an abundance (100% or over) of moisture at 100° C., for one hour, the whole mass becomes transparent and opalescent and the granules are intensely swollen.

Hall (1930) found that "starches from the crumb of a loaf of bread and the crumb of cake, examined before and after staining with Lugol's solution (I–KI) show a similar difference, the largest granules in the former measuring 35–45 μ and in the latter to 65 μ." The starch in cake appears to be more completely gelatinized than in bread.

The starches of different flours have different swelling powers. Hall states that "high viscosities of the gelatinized non-gluten constituents appear to be associated with high swelling powers and high water-imbibing powers."

Rask and Alsberg (1924) found high starch viscosity to be associated with two or more of the following conditions in the case of each flour: Low loaf volume; low protein content; high temperature of locality of growth.

Smith (1932) bleached different streams of Michigan wheat flour to a pH of approximately 5.4 with chlorine and compared them in a pound cake formula with the unbleached streams. He found "that in the streams of higher quality, chlorine bleaching increased the loaf volume significantly. In the middle grades the volumes tended to be about equal, while in the lower grades chlorine treatment definitely lessened the cake volume. It may be that this lessened volume is due to the heavy dosages required to overcome the buffering action of the flours in question—needing, as they did, four or five times as much chlorine as did the flours of lower ash content. In almost every case chlorine bleaching improved the symmetry of the test cake. In every case, down even to the poorest flours, chlorine treatment improved the grain of the test cake."

Alexander (1933) compared unbleached flour with flour bleached by the Brabender, Chlorine, Agene, and Novadel methods and found that chlorine gave the most marked improvement in the case of the white loaf cake formula developed by the A. A. C. C. Soft Wheat Flour Testing Committee. His results intimate that bleaching with chlorine may be undesirable in the case of sugar cookies, pie crust, fried cakes, and other pastries where spread, top grain, and shortness are important. He is also of the opinion that very fine granulation does not appear to improve the latter types of products.

Experimental

In the data reported in this article on granulation, maturing agents, quality and quantity of protein, etc., commercial pound cake, layer cake, and sponge cake formulae were used. The results of our experiments would, therefore, be expected to apply to commercial pound cake, box or slab cake, cup cake, layer cake, short sponge, sponge cake, and angel food cake.

Ontario soft winter wheat flours were used throughout in the study of cake flour quality, since the baker uses almost exclusively soft wheat flour in cakes and allied products. The following more or less basic cake formulae were used.

Commercial Pound Cake Formula

Ingredients			Method of incorporation
Sugar	100%	1 lb.	Cream together at medium speed for 10 minutes.
Shortening	50%	½ lb.	
Salt	1.6%	¼ oz.	
Whole eggs	50%	½ lb.	Add eggs slowly, cream 5 minutes.
Whole milk	50%+	½ lb.	Stir in milk, 5 revolutions on low.
Flour	100%	1 lb.	Sift flour and baking powder together. Mix for 2 minutes on low speed and 10 seconds on high.
Baking powder	0.6%	⅛ oz.	

Where different flours are being compared, a sufficient quantity of sugar, salt, and shortening are creamed together to suffice for all tests. The full amount of eggs for all tests are then added. One pound aliquot portions of the above mix are scaled into a three-quart mixing bowl and from here on the experiment is run as a single test, the milk being added with about five revolutions of the mixer on low and the flour mixed in as shown. The batter is scaled into pound cake tins at 13 ozs. (370 grams) and the product baked for 38 minutes at 375° F.

A single stage method of incorporating the ingredients was used occasionally, but in general we prefer the sugar-shortening creaming method described above.

Sponge Cake Formula

Flour	100%	1 lb.
Eggs	125%	1 lb. 4 oz.
Sugar	100%	1 lb.
Lemon extract	½%	3 cc.

Whip eggs and sugar for 12 minutes on high speed. The temperature during whipping is 95° to 100° F. Fold in the flour lightly by hand using a definite number of operations. Bake at 390° F. for 12 minutes.

COMMERCIAL LAYER CAKE FORMULA

Ingredients			Method of incorporation
Sugar	87%	7 oz.	Cream together approximately 10 minutes on medium speed.
Shortening	50%	4 oz.	
Salt	2%	¼ oz.	
Eggs	50%	4 oz.	Add eggs slowly, cream to desired volume (5–10 minutes).
Milk	50%	4 oz.	Stir milk in on low speed.
Baking powder	3%	¼ oz.	Sift together, stir in, mix 2 minutes on low, 10 seconds on high.
Flour	100%	8 oz.	

Scale creamed mass at 15 ozs.
Loaf cakes-pan at 13 ozs.
Layer cakes-pan at 7–8 ozs.
Loaf cakes bake at 380° F. for 30 to 35 minutes.
Layer cakes bake at 380° F. for 20 minutes.

When reading the results and observing the photographs, Figures 1 to 4, it should be kept in mind that these are comparative tests and that every condition must be as nearly identical as possible except the one that is being varied. If there is more than one ingredient or factor varying at once, one can arrive at no conclusion. It is realized that

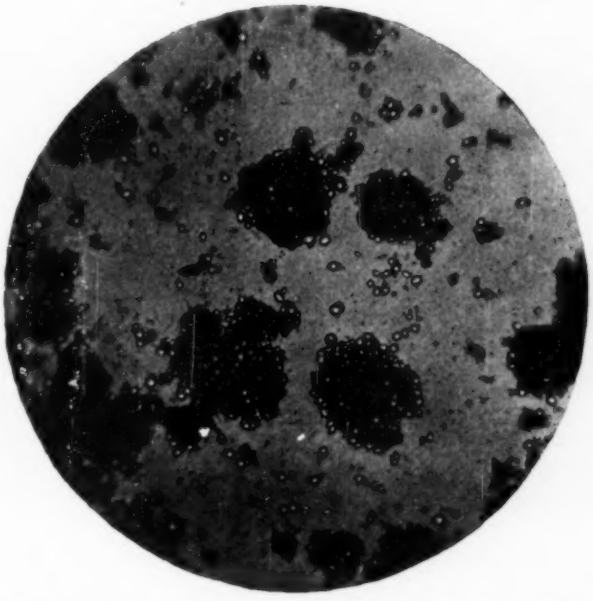

Fig. 1. Micro-photograph 9XX coarse flour. The coarse flour was suspended in water and lightly stained with iodine. A 9XX sieve will allow comparatively coarse granular flour to pass through the sieve. It will be noticed from the micro-photograph that the flour contains large bundles of starch granules surrounded by protein material. The number of free starch granules are comparatively few. Such flour tends to produce coarse cakes. Magnification 530.

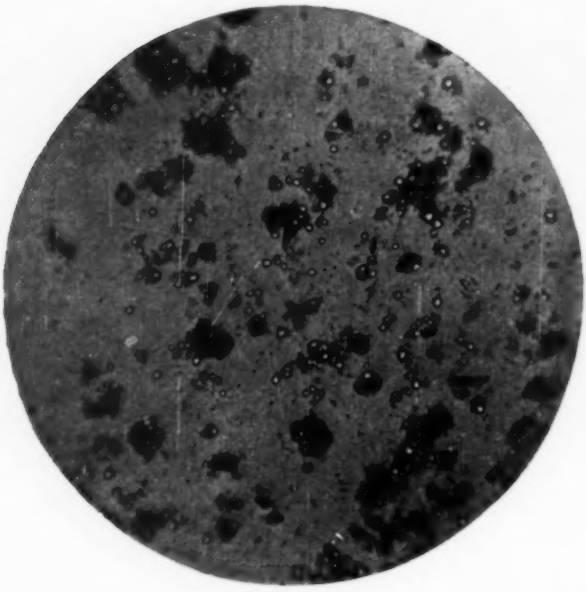

Fig. 2. Micro-photograph 25XX very fine. The flour in this case was very fine and soft. The starch and gluten bundles tended to be small in size with many free starch granules and gluten particles present. With properly matured flour of the correct quality and quantity of protein, this granulation gives very excellent cakes. Magnification 530.

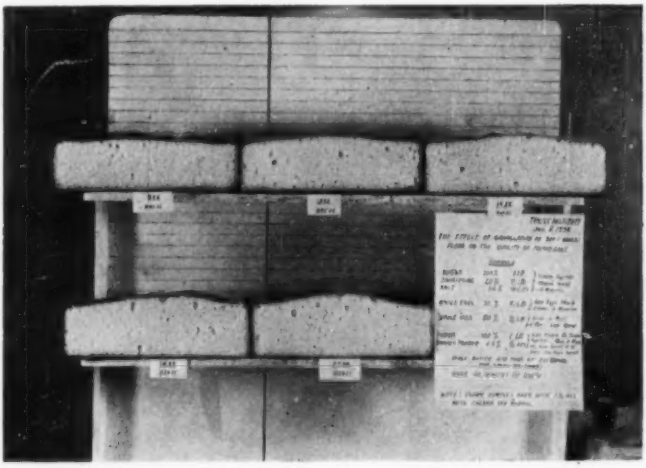

Fig. 3. The above photograph shows the effect of the fineness of the flour on the baking quality as shown in commercial pound cake. The cake produced from coarse flour (top left 9XX) had a coarse interior, low volume, and tended to be somewhat dry and crumbly. As the fineness of the flour increased in the order of 12XX top centre, 15XX top right, 18XX bottom left and 25XX bottom centre, the volume of the pound cake tended to increase, the grain and texture became finer and silkier and the general eating properties tended to improve.

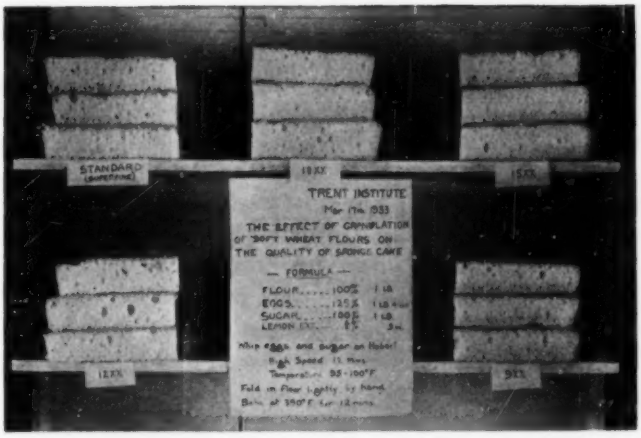

Fig. 4. The above photograph shows the effect of the fineness of the flour on the baking quality as shown in sponge cake. Sample 9XX bottom right was very slightly granular in feel and produced a cake of low volume and coarse interior properties. As the fineness of the flour increased in the order of 9XX bottom right, 12XX bottom left, 15XX top right, and 18XX top centre, the quality of the sponge cake improved. The volume tended to increase and the silkiness, lightness and eating properties of the sponge cake improved.

in most cases where cakes gave a very low score with a certain bleach, granulation and quality of protein, the quality of the product could be improved by certain alterations of the formula, principally with regard to sugar or liquid. The object of the tests, however, is to show the effect of changes in cake flour quality under standard conditions and without alteration of the formula

The Effect of Granulation on the Quality of Cake Flour

Ontario soft winter wheats were used throughout in the study of the effect of granulation on cake quality. In two series of tests, coarse middlings were obtained from a local mill and the products sifted that none would pass through a 9XX sieve. The coarse semolina or middlings was then thoroughly mixed so as to obtain uniformity throughout. The large sample was divided into several five-pound portions. These portions were ground on an experimental mill by a very gradual process of reduction (*i.e.*, by using 8 to 12 reductions) so as to pass through 9XX, 12XX, 15XX, 18XX, and 25XX sieves, respectively. In this manner, samples of flour of different degrees of fineness, but produced from exactly the same coarse middlings, were obtained The composition of the different flours of varying granulations were, therefore, approximately the same assuming very slight variations in fibre and ash. The experiment as carried out in the above manner is quite different from that which would be obtained if a given sample of commercial flour were sifted through sieves of the above granulations in

series so as to divide a sample of flour into its different granulations. The inside of the endosperm has not the same composition as the outside and if different granulations of flour were obtained by the latter method, appreciable variations in the protein quantity and quality might be expected.

In another series of tests, wheats of the 1932 crop and 1933 crop, respectively, were milled on an experimental mill so as to produce coarse middlings or semolina. The sample was then sifted so as to exclude all particles which would pass through a 9XX sieve. After thorough mixing the large sample was divided into several portions which were ground individually to different degrees of fineness. Flours of the different granulations were then baked out according to the formula given above. As previously stated, the results obtained would be expected to be true for such cakes as commercial pound, box or slab, cup cakes, layer cake, short sponge, sponge cakes, and angel food cake.

The samples shown in Table I were unbleached and this is the reason

TABLE I

THE EFFECT OF DIFFERENT GRANULATIONS OF SOFT WHEAT FLOUR ON THE BAKING QUALITY OF SPONGE CAKES (1932 CROP)

Baking Test Report on Sponge Cakes

	Score units	Flour passing through designated sieves			
		9XX	12XX	15XX	18XX
External appearance					
Symmetry	10	9.0	9.5	9.5	9.5
Volume	15	13.5	14.0	14.5	15.0
Crust sugariness	5	4.5	4.5	4.5	4.5
External score	30	27.0	28.0	28.5	29.0
Internal appearance					
Texture					
Tenderness	15	12.0	13.0	13.5	14.0
Silkiness	15	13.0	13.5	14.0	14.5
Grain	25	22.0	23.0	23.5	24.0
Crumb color	15	13.5 deep C-Y[1]	14.0 C-Y[1]	14.5 C-Y[1]	14.5 C-Y[1]
Internal score	70	60.5	63.5	65.5	67.0
Total score	100	87.5	91.5	94.0	96.0

[1] C–Y = cream yellow.

for the cream yellow color. Moisture content of the flour was 11.0%, ash 0.4%, and protein 7.4%.

It will be observed from Table I that the quality of the sponge cake improved with fineness of grind. The 9XX or coarse flour was low in volume and had a poor texture, grain, and crumb color as compared with

the samples of finer granulation. The sample of 18XX or very fine flour gave the best results producing a cake of excellent volume, symmetry, texture, grain and crumb color. The improvement in texture and grain was responsible for the improvement in crumb color. Similar comparative results were obtained in commercial pound cakes.

Tables II and III are of interest, since they demonstrate a factor not shown in the data of Table I.

TABLE II

THE EFFECT OF DIFFERENT GRANULATIONS ON THE QUALITY OF UNBLEACHED CAKE FLOUR

(Standard pound cake formula—unbleached flour 1933 crop)

	Score units	Flour passing through indicated sieves				
		9XX	12XX	15XX	18XX	25XX
External appearance						
Symmetry	10	7.5	8.0	8.5	7.5 Fell on cooling	7.0
Volume	15	12.5	13.0	13.0	12.5	12.5
Crust sugariness	5	3.5	4.5	4.5	4.5	4.5
External score	30	23.5	25.5	26.0	24.5	24.0
Internal appearancd						
Texture						
Tenderness	15	11.0	13.0	13.5	13.0	13.0
Silkiness	15	10.0	12.0	13.0	12.0	12.0
Grain	25	17.0	20.0	21.0	18.0	17.0
Crumb color	15	11.5 deep C[1]	13.0 C	13.5 C	13.0 C streaky	13.0 C streaky
Internal score	70	49.5	58.0	61.0	56.0	54.0
Total score	100	73.0	83.5	87.0	80.5	79.0
Volume, Cc.		810	850	850	820	800
Moisture %		10.9	10.3	10.9	10.7	10.8
Ash %		.36	.40	.38	.37	.37
Protein %		8.2	8.3	8.3	8.1	8.1

[1] Deep cream.

A rather strange phenomenon was observed in the tests reported in Table II. As the cakes came from the oven, the flours with the finest granulation gave the best external appearance and volume. However, on cooling, the cakes of fine granulation (*i.e.* 15XX, 18XX and 25XX) were found to recede and ultimately fall, resulting in soggy streaks and very poor external and internal appearance. Although the cakes of fine granulation obviously gave the best results on coming from the oven, yet they did not have the strength to stand up. It was thought that if these samples were matured with 1½ ozs. chlorine containing 1% nitrosyl chloride (or possibly chlorine) that the fine flours would not

fall as they came from the oven and that they would, therefore, produce the best cakes.

As was predicted, maturing with chlorine containing 1% nitrosyl chloride caused the cakes of fine granulation to stand up well. A glance at Table III will show that the finer the granulation the better the pound

TABLE III

THE EFFECT OF DIFFERENT GRANULATIONS ON THE QUALITY OF BLEACHED CAKE FLOUR

(Standard pound cake formula—each sample matured with 1½ ozs. chlorine containing 1% nitrosyl chloride per barrel—1933 wheat crop)

	Score units	Flour passing through indicated sieves				
		9XX	12XX	15XX	18XX	25XX
External appearance						
Symmetry	10	8.5	9.0	9.0	9.5	9.5
Volume	15	13.0	14.0	14.5	14.5	14.5
Crust sugariness	5	4.0	4.5	4.5	4.5	4.5
External score	30	25.5	27.5	28.0	28.5	28.5
Internal appearance						
Texture						
Tenderness	15	12.0 harsh	13.0	13.5	13.5	14.0
Silkiness	15	11.5	13.5	14.0	14.0	14.5
Grain	25	19.0	21.0	22.5	23.0	23.5
Crumb color	15	12.5 C	13.5	14.0	14.5	14.5 C-W
Internal score	70	55.0	61.0	64.0	65.0	66.5
Total score	100	80.5	88.5	92.0	93.5	95.0
Volume, Cc.		840	895	910	920	920

cake produced. This is shown in volume, symmetry, texture, grain, and crumb color.

In ordinary milling practice, it is difficult to obtain the very fine granulations. For bread flours, it is usually customary to use a 10XX to 12XX sieve for the flour. Grinding to finer granulations requires more power and more bolting and sifting equipment. Moreover, the bolting cloths are apt to clog and other difficulties have to be overcome. In the case of soft wheat flours, some mills are now using a 14XX sieve for bolting which gives a fine flour, a large proportion of which passes through a 25XX sieve. The fineness of the flour may also be increased by reducing the feed and increasing the pressure on the reduction rolls.

The Effect of Different Percentages of Bleach on the Quality of Cake Flour

The addition of the proper kind of aging and maturing agents to Ontario soft winter wheat flours in the correct amounts has a marked

effect upon the baking quality as shown in pound cake, sponge cake, layer cake, and angel food cake. Chlorine containing 1% nitrosyl chloride (Beta Chlora) and chlorine appear to be the most successful maturing agents used for this purpose. The two maturing agents mentioned markedly increase the acidity or hydrogen-ion concentration, and appear to produce other changes in the flour not very well understood.

James and Huber (1927) raised the acidity of flour by treating it with hydrogen chloride gas and compared it with a similar sample of flour whose hydrogen-ion concentration had been raised by the addition of chlorine. Working with hard wheat flours, they found "that the small amount of hydrogen chloride liberated by the action of chlorine on the flour is only sufficient to account for a small portion of the effect of chlorine. They felt that the principal effect of chlorine on the flour and flour gluten must be that of oxidation."

Chlorine containing 1% nitrosyl chloride (Beta Chlora) was used throughout in the data reported in this article. In one series of experiments, samples of first patent, second patent, third patent, and first clear flour were obtained from a local mill. Each sample was thoroughly mixed to ensure uniformity and was divided into 500-gram aliquot portions. These portions were treated with different amounts of Beta Chlora. An experimental agitator supplied by the Wallace and Tiernan Company was used for applying the bleach. The agitator in question is not absolutely air-tight and it is possible there were slight losses of gas. The analysis of the different flours are given in Table IV.

TABLE IV
CHEMICAL ANALYSIS OF FLOURS USED IN BLEACHING

	Ash	Protein
	P.ct.	*P.ct.*
1st Patent (?)	0.43	8.2
2nd Patent	.42	8.5
3rd Patent	.53	9.4
1st Clear	.66	9.1

The first patent flour represented about 40% extraction, the second patent about a 75% extraction, the third patent about a 95% extraction with the first patent flour removed, and the first clear the last 20% of the extraction excluding the low grade flour. The ash content of the first patent flour would indicate that it more closely approached a second patent, although the protein content would indicate a first patent flour. Table V represents a summary of the data obtained in these tests. The "grand total" represents the total score obtained by each treatment as shown in commercial pound cake.

TABLE V

EFFECT OF BETA CHLORA ON pH AND QUALITY OF POUND CAKE

Ozs. Beta Chlora per bbl. flour	0	1	1½	2	3	3¾	4½
1st Patent flour							
pH	6.07	5.79	5.59	5.48	5.30	5.1	4.87
Grand total[1]	72.5	79.5	85.5	91.0	93.0	94.5	94.5
Volume, Cc.	610	690	770	800	895	910	905
2nd Patent flour							
pH	6.06	5.90	5.75		5.48	5.12	4.67
Grand total[1]	72.0	83.0	88.0		90.0	92.5	92.0
Volume, Cc.	600	770	790		870	890	875
3rd Patent flour							
pH	6.18	5.97	5.86	5.775	5.55	5.03	4.83
Grand total[1]	69.0	78.0	81.5	87.0	87.0	89.0	89.5
Volume, Cc.	660	840	840	880	885	890	900
1st Clear flour							
pH	6.24	6.01	5.94	5.89	5.78	5.13	4.71
Grand total[1]	65.5	74.5	77.5	80.0	86.5	85.5	84.0
Volume, Cc.	690	800	800	820	875	875	875

[1] Total cake score obtained by each treatment.

A part of the data presented in Table V is shown in Figures 5, 6 and 7. It will be noted from Figure 5 that there appears to be almost a straight line relation between the ounces of Beta Chlora added and the decrease in hydrogen-ion concentration. The higher the buffer value or ash content of the flour, the greater the amount of Beta Chlora required to produce a definite decrease in hydrogen-ion concentration.

From Figure 6, the total score of the pound cake is seen to rise rapidly with the addition of from 0 to 2 ozs. Beta Chlora; with 2 to 3 ozs. the rise tends to be less pronounced, and after 4 ozs. Beta Chlora are added, the score tends to remain stationary or decrease with the exception of the third patent flour. It will be noted from Figure 6 that 2 to 3 ozs. Beta Chlora gives almost optimum results in all cases.

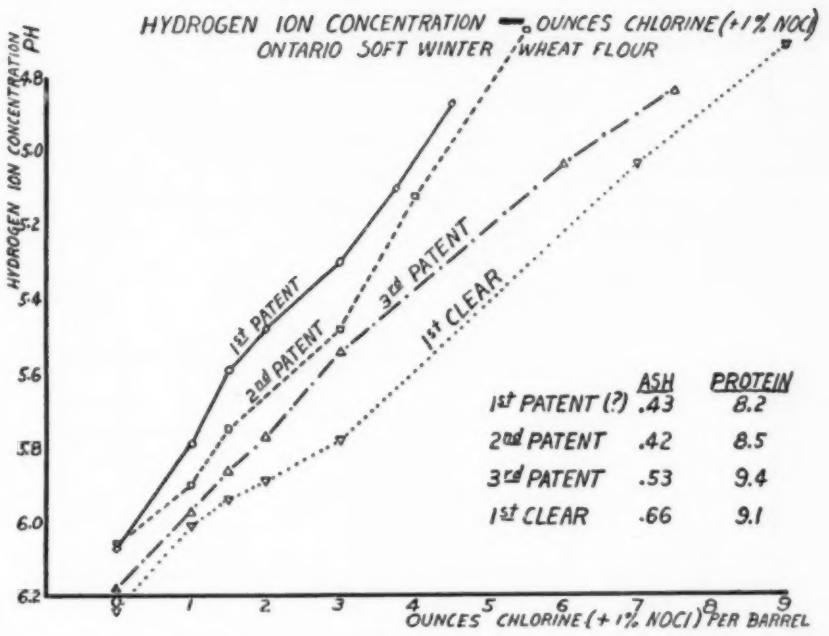

Fig. 5. The effect of different amounts of chlorine containing 1% nitrosyl chloride on the hydrogen ion concentration of flour suspensions.

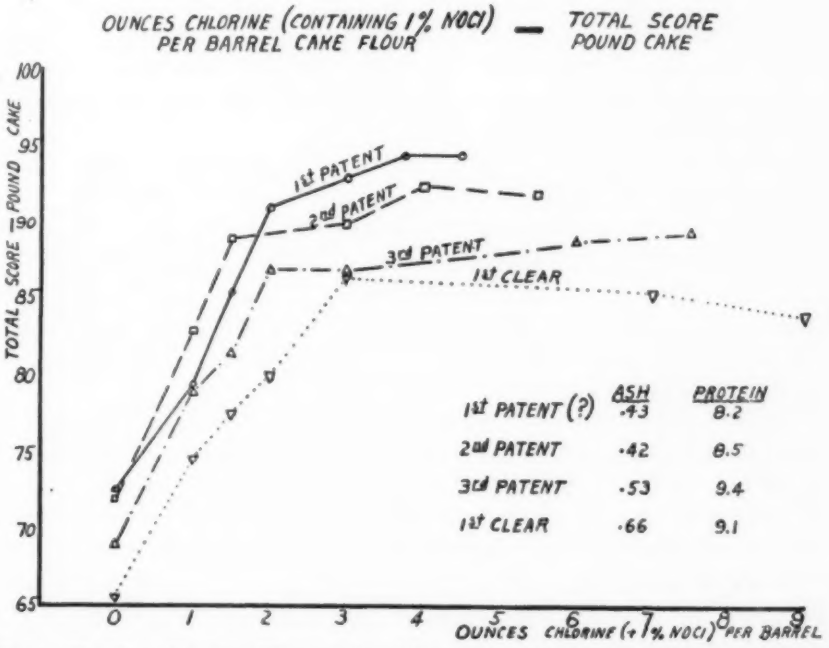

Fig. 6. The effect of treating different grades of flour with varying amounts of chlorine containing 1% nitrosyl chloride on the total score of pound cake produced therefrom.

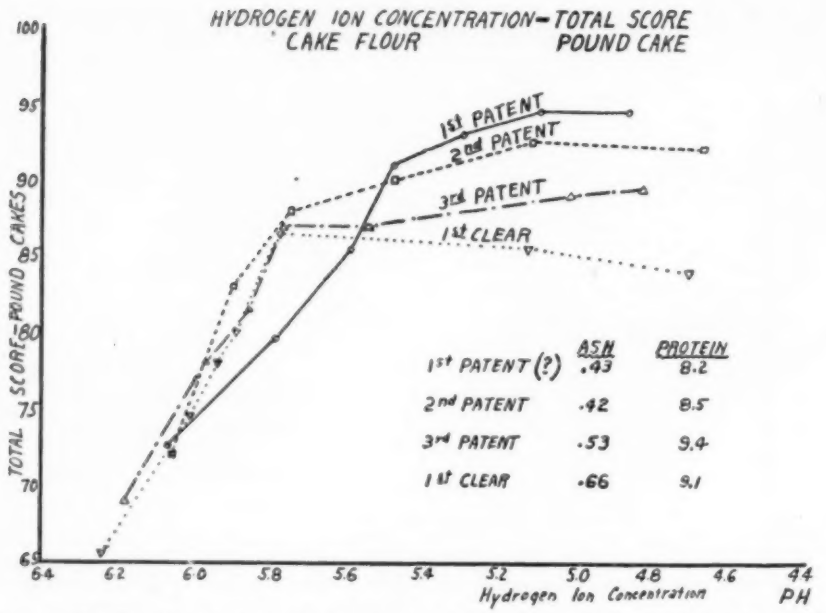

Fig. 7. The effect of the hydrogen ion concentration of cake flour suspensions on the total score of pound cake produced therefrom.

This improvement is most apparent in volume, crumb color, grain, texture, smoothness in eating, and keeping quality of the cake. Pound cakes, containing no treatment with Beta Chlora or with small amounts, tended to have fair volume as they came from the oven, but fell badly during the first few minutes of cooling.

It will be noted from Figure 7 that the first and second patent flours reached about an optimum baking value at a pH of about 5.1. The first clear flour reached an optimum baking value at a pH of about 5.8.

Table V (see also Figure 8) indicates that about optimum loaf volume was obtained in all cases by the addition of about 3 ozs. Beta Chlora. Optimum volume was reached at about a pH of 5.8 in the case of first clear and third patent flours, and at a pH of about 5.1 in the case of first and second patent flours.

It is realized that the data are entirely insufficient to warrant any general statements. The above tests should be repeated on different grades of flour a number of times and for different crop years.

Numerous tests have been carried on at the Trent Institute during the past three years using different amounts of Beta Chlora on Ontario soft winter wheat flour. These represent both commercial and experimental runs. In many cases of flours having an ash of 0.40% to 0.47%, it was found that about optimum baking results were obtained by the

addition of from 1½ to 2 ozs. Beta Chlora per barrel of flour. Hydrogen-ion concentrations were not run on the majority of these flours and therefore the value of the data is limited.

In the cases where no or small amounts of Beta Chlora were used, it should be understood that the volumes of the cakes were reasonably good as they came from the oven. However, unbleached flours tended to fall badly after coming out of the oven and this accounts largely for their very low volume. It is quite possible that by decreasing the liquid and sugar and increasing the flour, the cakes would not have fallen with untreated flour. However, these changes would tend to make the cake tougher and more unpalatable.

Alexander (1933) found that although chlorine improved the cake baking properties of cake flours, this was not the case where the flours were used for pastry purposes. His results indicated that in the case of sugar cookies, pie crust, fried cakes, and other pastries, where spread, top grain, and shortness are important, that chlorine treated flours gave less satisfactory results than unbleached flours.

Preliminary tests carried on at the Trent Institute indicate that cookies made with unbleached flour had greater spread, nicer appearance, and richer bloom than cookies from bleached flour. Bleached flour gave cookies with better symmetry of shape, smoother top grain, and slightly moister crumb. In the case of pie pastry, differences were not significant. Pie pastry from unbleached flour had slightly the better crust color and bloom.

Effect of Quantity and Quality of Protein on the Quality of Cake Flour

In the case of bread flours, it was found that the loaf volume tends to increase as the percentage of protein increases. At one time the bread baking test was used to indicate the quality of soft wheat flours. This test was developed at a time when Ontario soft winter wheat was used for both bread and pastry purposes. Although the quantity and quality of protein as well as the bread baking test may be a good indication of the quality of bread flour, yet we have to bring in reservations when talking about soft wheat flours. We have thus found that high protein Ontario soft wheats do not tend to give the best cake flour. On the contrary, the tendency is for the low protein wheats to give the best results. Dawson's Golden Chaff wheat is amongst the lowest in protein content and yet is amongst the best in baking properties. Insufficient work has been done on Ontario wheat varieties from a cake baking standpoint to make any general statements at the present time.

It has been observed that a crop producing high protein wheats tends to produce tougher cakes than a low protein crop in the case of Ontario soft winter wheats which may be expected to be similar to Michigan wheats, etc. As an example of this, the 1932 crop of Ontario winter wheat was very low in protein content, the protein content of the wheat being around 7.5 to 9.0% and of patent flour between 7 to 8%. On the other hand, the 1933 crop was comparatively high in protein, the wheat being between 9.0 to 10.5% and the patent flour between 8.5 to 10.0%. The 1933 crop tends to produce slightly tougher cakes and of a more bready character than the 1932 crop. This tends to indicate that low protein crops are the more desirable.

The quality of gluten varies from runny glutens that are difficult to handle, to glutens that are tough, tending to resemble glutens from spring wheat flours. Glutens that are difficult to wash and yet have good elasticity are desirable. The addition of maturing agents such as chlorine containing 1% nitrosyl chloride and chlorine markedly changes the nature of the gluten, making it more elastic and allowing it to form thinner films.

The length of the extraction of the flour in milling has an effect upon the cake baking properties. Short patent flours have a lower protein content and in the case of Ontario soft winter wheats appear to give

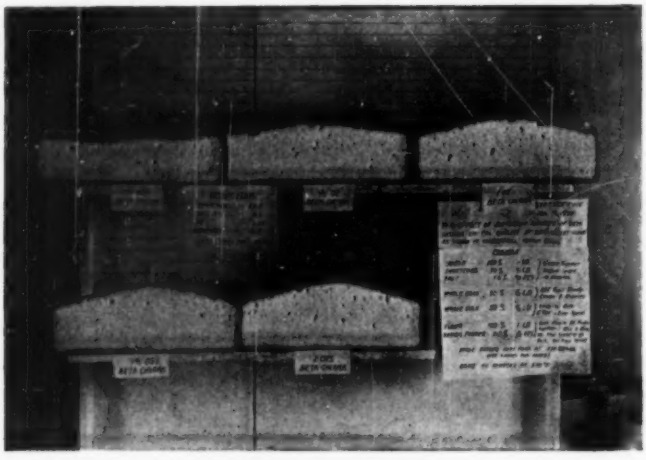

Fig. 8. This photograph shows the effect of maturing Ontario soft winter patent cake flour with different amounts of chlorine containing 1% nitrosyl chloride. The pound cake produced from untreated flour, top left, fell after coming from the oven. The cake had a coarse grain, soggy streaks, and a dry, poor taste. It is understood that this cake would have stood up better if the moisture, sugar, etc., had been decreased, but the cake would not have had the eating properties of the cakes treated with the proper amount of chlorine containing 1% nitrosyl chloride. As the percentage of Beta Chlora was increased in the order of ½ oz. Beta Chlora top centre, 1 oz. Beta Chlora top right, 1½ oz. Beta Chlora bottom left, and 2 oz. Beta Chlora bottom centre, the pound cake tended to improve in volume, grain, texture, color, moistness, and general eating properties.

lighter, whiter, and more tender cakes than long patent flours containing higher percentages of protein, fibre, and ash.

Moisture Content of Flour

The law requires that the moisture content of flours should not be over 13.5% in Canada. This is equivalent to about 15% in the United States. The official moisture method for flour in Canada consists of heating flour in an air-oven overnight at 100° C. The official method for running moisture in Canada gives results which are 1 to 1½% lower than the official vacuum oven method in the United States. The majority of Canadian research laboratories use the official A. A. C. C. vacuum oven method. Cake flours containing higher moistures than these amounts tend to cake readily and go out of condition if kept under warm, moist conditions.

Cake flours of very fine granulation tend to cake slightly more readily than coarsely ground flours as might be expected. One should, therefore, endeavour not to confuse moistness and fineness of grind. It is important to sift the flour before use to eliminate the possibility of lumps in the cake batter.

General Conclusions

From the limited number of tests carried on to date, it would appear, in the case of commercial pound cake, sponge cake, layer cake, and angel food cake—

That the finer the flour the better from a cake baking standpoint;

That the addition of the correct amounts of chlorine containing 1% nitrosyl chloride (Beta Chlora) markedly improved the baking properties of cake flours; and,

That low protein wheat crops appear to produce better cakes than high protein wheat crops.

The above holds good for Ontario soft winter wheat flour.

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THE INFLUENCE OF ENVIRONMENT ON THE CAROTENOID CONTENT OF HARD RED SPRING WHEAT [1]

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(Presented at the Annual Meeting, June, 1934)

In the development of new varieties of hard red spring wheat in Canada, the determination of their quality characteristics is an essential part of the programme and since there is a preference on the part of mills for wheat producing flour relatively low in yellow pigmentation, carotenoid determinations play an important rôle in the evaluation of new sorts. In recent years the Cereal Division of the Dominion Experimental Farms Branch, chiefly at the Dominion Rust Research Laboratory, Winnipeg, and the Dominion Experimental Farm, Brandon, and the Universities of Manitoba, Saskatchewan, and Alberta have been active in the breeding of disease resistant varieties, the first three named institutions concentrating chiefly on rust resistance. In 1933, a series of 36 varieties including 4 standard varieties, 29 of the most promising sorts produced in Canada in this programme to date, and 3 from the United States were grown in comparative test plots at a number of points in the provinces of Manitoba, Saskatchewan, and Alberta. In the study of the quality characteristics of these wheats grown at 9 locations, distributed over a wide area as shown in the map (Figure 1), an opportunity was afforded to determine the effect of environment on the carotenoid content of the flours milled from them.

Methods

The carotenoid pigmentation, expressed as carotene in parts per million on the straight grade, freshly milled flours, was determined by the colorimetric method outlined by Geddes, Binnington, and Whiteside (1934). This involved the extraction of 20 gms. of flour with 100 cc. of the naphtha-alcohol solvent, suggested by Ferrari (1933), consisting of 93 parts by volume of high grade re-distilled varnish makers naphtha and 7 parts of absolute ethyl alcohol and matching the extracts with known standards of potassium chromate solutions using the light source from mercury arc radiation. In the adaptation of this method to

[1] Published as paper No. 69 of the Associate Committee on Grain Research, National Research Council of Canada and the Dominion Department of Agriculture.

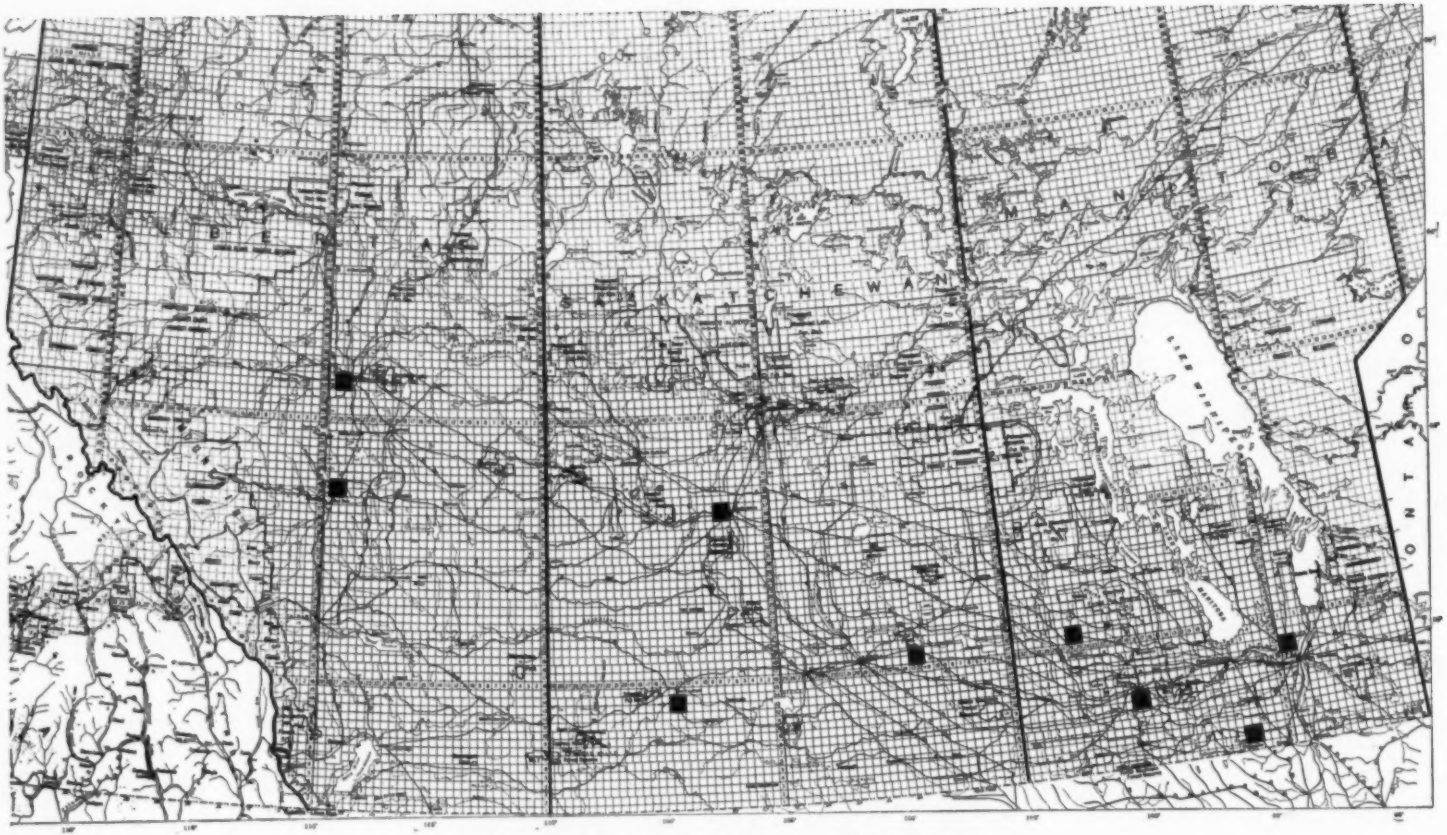

Fig. 1. Map showing the 9 locations where the wheat samples were grown.

routine work in our laboratory, two innovations in technique were evolved.

Clarifying colour extracts of flour either by centrifuging or by the use of Jena or paper filters in the usual way is a slow process, not well adapted to routine analyses. In order to clarify the solutions as rapidly as possible, 1 cc. of a strong solution of NaOH is added in the morning and after a few moments the whole is vigorously shaken, allowed to settle out and then filtered. For more stubborn suspensions 1 cc. of a 20% solution of NaOH was found adequate without affecting the determination. This procedure allows for rapid filtration and the substitution of a more porous filter paper such as a No. 4 Whatman.

In Figures 2 and 3 are shown an especially constructed colorimeter

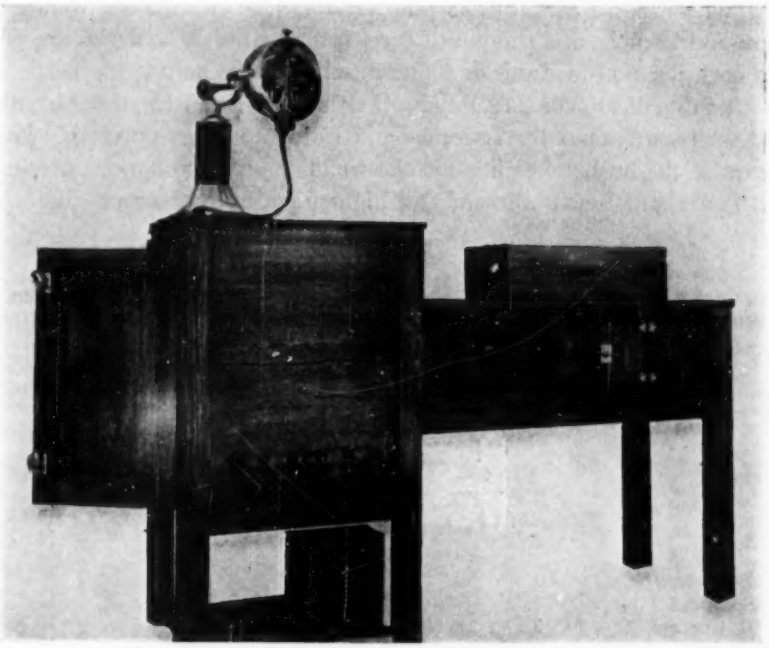

Fig. 2. Colorimeter showing Alpine sun lamp superimposed on lamp housing. The box containing the colour standards on upper right moves on a track past the tube containing the unknown located in the centre.

consisting of a housing for an Alpine sun lamp and an arrangement for moving the standard solutions contained in colorimetric glass tubes past a tube containing the unknown. The matching is done by looking through the depth of the liquid illuminated by the light from the mercury arc lamp reflected from a plate glass coated with magnesium oxide.

Fig. 3. Box showing location of tubes for colour standards. The tube for the unknown is placed in a fixed position in the central block.

The Data

The mean carotene of the flour, test weight per bushel, weight per thousand kernels, and protein of the wheat for the 36 varieties are given for each location in Table I. The mean carotene values for Birtle and Swift Current are considerably higher than the mean for the 9 locations and the mean values for Lacombe and Edmonton are appreciably lower. Likewise the bushel weights and the weights per 1000 kernels are lower for Birtle and Swift Current and higher for Lacombe and Edmonton.

TABLE I

THE MEAN CAROTENE, TEST WEIGHT PER BUSHEL, WEIGHT PER 1000 KERNELS, AND PROTEIN CONTENT FOR THE 36 VARIETIES GROWN AT EACH OF 9 LOCATIONS

Location	Flour carotene	Test weight [1] per bushel	Weight per 1000 kernels	Crude protein in wheat
	P.p.m.[2]	*Lbs.*	*Gms.*	*Pct.*
Manitoba				
Winnipeg	2.04	64.59	30.79	14.14
Morden	1.89	63.82	32.14	16.36
Brandon	2.06	63.78	32.94	14.45
Birtle	2.32	60.84	25.44	16.83
Saskatchewan				
Indian Head	1.92	62.95	34.36	15.61
Swift Current	2.59	60.06	24.55	15.78
Saskatoon	1.92	62.91	30.36	15.63
Alberta				
Lacombe	1.79	63.63	37.54	15.81
Edmonton	1.76	64.92	38.36	15.21
Means	2.03	63.05	31.83	15.54

[1] Imperial bushel 2218 92 cubic inches.
[2] Parts per million.

In Table II data for 4 standard and 4 numbered varieties grown at Birtle, Swift Current, Lacombe, and Edmonton, and the mean for these

TABLE II

FLOUR CAROTENE, TEST WEIGHT PER BUSHEL, WEIGHT PER 1000 KERNELS, AND PROTEIN FOR 4 STANDARD AND 4 NUMBERED VARIETIES GROWN AT EACH OF 4 LOCATIONS, AND MEAN FOR THE VARIETIES FOR THE 9 LOCATIONS

Location	Variety	Flour carotene	Test weight per bushel [1]	Weight per 1000 kernels	Crude protein in wheat
		P.p.m.[2]	*Lbs.*	*Gms.*	*Pct.*
Birtle	Marquis	1.95	61.3	23.8	17.1
	Reward	1.95	64.4	27.6	16.9
	Ceres	2.00	61.8	24.4	17.3
	Huron	2.25	62.0	26.8	16.9
	112	1.82	61.2	25.8	17.8
	301	3.40	61.7	28.1	17.5
	402	3.30	61.0	31.2	17.8
	502	1.95	63.5	27.3	17.3
Swift Current	Marquis	2.08	61.2	23.3	14.8
	Reward	2.02	64.6	27.9	15.4
	Ceres	2.15	61.9	23.9	15.3
	Huron	3.00	58.5	21.5	15.5
	112	2.00	60.3	24.4	15.7
	301	3.60	61.1	26.6	15.7
	402	3.40	60.1	31.4	17.0
	502	2.20	61.3	24.9	15.6
Lacombe	Marquis	1.85	64.0	37.3	15.6
	Reward	1.70	65.5	35.7	17.0
	Ceres	1.67	63.1	35.3	16.7
	Huron	1.80	63.4	38.4	15.0
	112	1.35	63.4	39.1	15.5
	301	2.50	64.3	39.8	16.2
	402	2.80	62.2	41.8	16.7
	502	1.65	64.0	37.2	15.9
Edmonton	Marquis	1.50	65.2	36.4	15.3
	Reward	1.55	66.6	37.5	16.7
	Ceres	1.60	65.5	36.9	15.7
	Huron	1.92	65.5	38.8	14.7
	112	1.38	64.9	40.6	14.9
	301	2.50	63.3	40.4	15.0
	402	2.40	62.9	43.4	16.7
	502	1.70	65.5	36.6	14.9
Mean for 9 locations	Marquis	1.78	63.8	30.5	15.3
	Reward	1.81	65.3	32.0	16.3
	Ceres	1.85	64.0	30.8	15.8
	Huron	2.27	62.8	31.3	15.1
	112	1.60	63.0	32.8	15.2
	301	2.84	63.3	35.0	15.7
	402	2.79	61.8	36.7	17.0
	502	1.76	64.0	32.2	15.4

[1, 2] See footnotes 1 and 2, Table I.

8 varieties for the 9 locations are given. It is obvious from Tables I and II that two factors have a bearing on the carotene values obtained, namely, environmental effects and inherent varietal characteristics. Under these circumstances it appeared that covariance analysis was a convenient statistical method for handling the data.

Analysis of Covariance

The primary purpose of this study, as already pointed out, was to determine the effect of environmental factors on carotene, hence in a study of the correlation between such characters as weight of 1000 kernels and carotene content of the flour, in data obtained for a series of varieties tested at several stations, it is necessary to sort out the effects of variety and district and the interaction of these two factors.

The most convenient method for accomplishing this end is that of covariance analysis. An example of the method showing its relation to the analysis of variance as applied to any one character is given below.

Assuming that a study is to be made of the relation between 1000 kernel weight and carotene content the analyses of variance for the two variables are first set up. These are given in Table III.

TABLE III

ANALYSES OF VARIANCE FOR 1000 KERNEL WEIGHT AND CAROTENE CONTENT

Variance due to	Sum of squares	Degrees of freedom	Variance
1000 Kernel Weight			
Districts	6483.53	8	810.44
Varieties	759.13	35	21.69
Residual	483.03	280	1.73
Total	7725.69	323	23.92
Carotene Content			
Districts	20.34	8	2.54
Varieties	23.31	35	.67
Residual	4.39	280	.06
Total	48.04	323	.15

The analysis of covariance makes use of the principle that the sums of products may be subdivided in the same manner as the sums of squares. These sums of products may be calculated according to the following formulae, where x may be taken to represent 1000 kernel weight and y the carotene content.

Total $$S(x - \bar{x})(y - \bar{y}) = S(xy) - \frac{TxTy}{N}$$

Districts $$S(\bar{x}_d - \bar{x})(\bar{y}_d - \bar{y}) = \frac{S(TxdTyd)}{n} - \frac{TxTy}{N}$$

Varieties $$S(\bar{x}_v - \bar{x})(\bar{y}_v - \bar{y}) = \frac{S(TxvTyv)}{k} = \frac{TxTy}{N}$$

Residual = Total − (districts + varieties)

Tx = total for 1000 kernel weight
Ty = " " carotene content
$\bar{x}_d$ = mean of x for any one district
$\bar{x}_v$ = " " x " " " variety
$\bar{y}_d$ = " " y " " " district
$\bar{y}_v$ = " " y " " " variety
k = number of districts
n = " " varieties
$N = (nk)$ = total number of pairs.

For the two variables mentioned the subdivision of the sums of products is as in Table IV.

TABLE IV

SUMS OF PRODUCTS FOR 1000 KERNEL WEIGHT AND CAROTENE

Source	Sums of products
Districts	−328.88
Varieties	56.62
Residual	− 23.64
Total	−295.90

Either of the components of the Tables III and IV may be used to calculate correlation coefficients. Calculating these we obtained the coefficients as follows:

Districts $$\frac{-328.88}{\sqrt{6483.53 \times 20.34}} = -.9056$$

Varieties $$\frac{56.62}{\sqrt{759.13 \times 23.31}} = .4257$$

Residual $$\frac{-23.64}{\sqrt{483.03 \times 4.39}} = -.5133$$

Total $$\frac{-295.90}{\sqrt{7725.69 \times 48.04}} = -.4857.$$

The significance of the above correlations may be obtained by taking as the degrees of freedom for entering one less than those given in the analysis of variance table (Fisher's table of t (1932)). Thus for the "district" correlation we have only 7 degrees of freedom; for varieties 34, residual 279, and total 322. The correlations and their respective t values are therefore as follows:

	Correlation coefficient	t
Districts	−.9056	5.65
Varieties	.4257	2.74
Residual	−.5133	9.99
Total	−.4857	9.97

It will be observed that all of the coefficients are significant and it remains to give a reasonable interpretation of their values. The correlation for districts is the same as would be obtained by correlating the 9 district means for the two variables. In this case it represents the degree to which 1000 kernel weight and carotene vary together as from district to district and is a measure of environmental influence in that climatic and soil conditions that raise the 1000 kernel weight are obviously accompanied by low carotene values. However, since there are only 9 distinct environments there are only 7 degrees of freedom with which to measure this effect and the correlation must be very high in order to be significant. The correlation for varieties is positive indicating merely that the varieties with high kernel weight tend to give high carotene values. This is a result of particular combinations of genetic factors and is of no importance in this study. It is calculated merely to remove the varietal effect. The residual correlation is somewhat more difficult to interpret but this becomes clear if we remember that after the varietal covariance is removed the remaining covariance may be considered as made of two parts, one for districts and a second for within districts. After also removing the covariance for districts we have remaining that portion of the total not common either to districts or varieties, which is the residual. In the residual the covariance effects are largely due to environment but the larger environmental effects have been removed with the district covariance. In general, the coefficient of correlation for the residual effect will agree with that for districts although the latter will usually be greater. From this it might be inferred that the two effects could be pooled in one correlation but in doing this there is some difficulty in testing the significance of the resulting coefficient. For example, the analysis of covariance on this basis for 1000 kernel weight and carotene is as follows:

Varieties	.4257
Remainder	—.8492
Total	—.4857

and it would be incorrect to test the significance of the second correlation on the basis of 287 degrees of freedom. In the corresponding analysis of variance the degrees of freedom would be allotted as follows:

Varieties	35
Remainder	288
Total	323

and it might be assumed that the degrees of freedom for the remainder would be $(288-1)=287$. However, the district effect which may be predominant is actually represented by only 8 degrees of freedom

and it follows that the logical method of testing the significance of the coefficient — .8492 is to split it up into its components. As will be noted above, this results in the two coefficients, — .9056 for districts and — .5133 for the residual. Both of these are significant but this does not follow necessarily from the apparent significance of the coefficient — .8492. It is conceivable that both components might be insignificant in which case the correlation from which they were obtained would also be insignificant regardless of first appearances.

In Table V the analyses covariance is given for bushel weight and carotene, kernel weight and carotene, and wheat protein and carotene.

TABLE V

ANALYSES OF VARIANCE AND COVARIANCE

Bushel weight (w), kernel weight (k), wheat protein (p), and flour carotene (c)

	Total	Districts	Varieties	Residual	Districts + Residual
			Sums of products		
wc	— 143.78	— 107.675	— 24.592	— 11.211	— 118.886
kc	— 295.90	— 328.881	56.623	— 23.638	— 352.519
pc	31.843	13.009	16.712	2.122	15.131
			Sums of squares		
w	1076.81	765.09	232.80	78.92	844.01
k	7725.69	6483.53	759.13	483.03	6966.56
p	393.36	205.90	100.01	87.45	293.35
c	48.04	20.34	23.31	4.39	24.73
			Correlation coefficients		
wc	— .6308	— .8631	— .3338	— .6024	— .8230
kc	— .4857	— .9056	.4257	— .5133	— .8492
pc	.2317	.2010	.3461	.1083	.1776

Test Weight per Bushel and Carotene

The correlations for total, districts, varieties, residual, and districts + residual are negative. The variety correlation indicated that in this particular series those varieties which tended toward higher carotene tended toward lower bushel weight. However, district, residual, and district + residual correlations, which bring out the influence of environment, indicate quite clearly that when bushel weight decreased the carotene content increased.

Weight per 1000 Kernels and Carotene

Kernel weight gives a measure of the comparative size of the wheat kernels of different varieties but in addition is influenced by their plump-

ness. As pointed out in the explanations of the statistical analyses used in this study, the varieties which tended toward higher carotene were tending toward higher weight per 1000 kernels but when subjected to different environments, the factors which tended to lower kernel weight tended to increase carotene content.

Wheat Protein and Carotene

The varieties at any one location tending toward higher protein tended toward higher carotene but there was no significant correlation between carotene and wheat protein due to environmental factors.

Summary

Environment has an appreciable effect on the carotenoid pigmentation of flour milled from wheats grown under different conditions. The effect of inherent characteristics was apparent in that there was a tendency for those varieties which produced higher carotene values to be higher in kernel weight, lower in bushel weight, and higher in wheat protein. The study brings out very clearly that carotenoid pigmentation is an inherent characteristic and substantiates the conclusions of Whiteside (1931) that samples of the same variety may be expected to vary considerably in carotenoid content and that the environmental conditions which tend to produce higher carotene values tend to produce lower bushel weight and lower kernel weight. There is no indication in this series that there is any correlation between flour carotene and wheat protein due to environmental factors. The necessity of subjecting varieties to comparable environmental conditions before relative values for their carotenoid contents may be obtained, is apparent. It also indicates that in areas or seasons where environmental conditions tend to produce plump wheat the carotenoid content of the flour milled from that wheat should be lower than where the conditions are the reverse.

Acknowledgments

The authors are indebted to P. R. Cowan for photographs and to J. Ker for assistance in constructing the apparatus.

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STUDIES ON THE VITALITY OF WHEAT. III. VITALITY, AND THE ACTION OF HEAT ON WHEAT SEEDS

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We have indicated elsewhere that any consideration of vitality of seeds involves both germinative power (or capacity for germination under suitable conditions, calculated as total percentage germination after all possible seeds have sprouted) and germinative energy (or speed of germination under standard conditions calculated as percentage germination in fixed periods of time). The influence of slow desiccation over calcium chloride in encouraging longevity and in increasing germinative energy of wheat seeds has also already been discussed (Papers I and II of this series).

Carruthers (1911) stated that it was "no chemical alteration produced by temperature, but the steady loss of moisture going on continually at ordinary air temperature" that was responsible for the loss of life in the seeds he examined. We know, however, that, in preserving vitality in seeds, moisture and temperature are inter-related, and that the lower the moisture the lower the temperature that can be imposed without loss of life and with encouragement to longevity. Moderate temperatures around 30° C., the *optimum* for wheat, and sufficient moisture, say around 25% of the weight of wheat, will, of course, bring about speedy germination which is indicative that the *dormancy* of the seeds has ceased to exist and that life has become *active*. Stratification at low temperatures, after-ripening, or treatment of seeds around 5° C. in the presence of enough moisture to cause germination but with germination suppressed by the low temperature, we also know now, from the work of Crocker and others, brings many seeds to a point where any increase in temperature, especially to the *optimum* for any particular seed, causes rapid germination more particularly marked in cases of seeds with a tendency to so-called "delayed germination."

Though it is difficult, therefore, to understand exactly what Carruth-

[1] The British Arkady Co. Ltd., Manchester, England.
[2] Peek-Frean & Co. Ltd., London, England.

ers (1911) meant in his statement quoted above, we cannot ignore the fact that any frequent movement of cell juices, whether caused by fluctuations of storage temperature or of atmospheric humidity, affects seeds adversely so far as retention of vitality is concerned, and will be reflected in time in a decreased germinative energy also. One of us has called attention to the loss of mineral matter from wheat during the course of several years' storage, and was able to show that much of this loss could be attributed to the deposition of mineral salts on the outside of the berry due to ex-filtration of soluble matters from the inside, which were subsequently lost by mechanical rubbing after they had dried out.[3] We do not know, however, what part, if any, this loss of mineral matter with age plays in loss of vitality or of germinative energy: nor are we very clear concerning the permeable or semi-permeable nature of the seed-coat of wheat since, with the exception of the work done by Schröder (1911) and Shull (1913) with wheat, most experiments have been made with other cereals—barley (Brown, 1909), rice (Scofield, 1905), etc. The work of Loeb (1906) on animal protoplasmic membranes and of Rufz de Lavison (1911) on vegetable cells would indicate the great importance of mineral salts in hardening and in providing rigidity to both surface films and the general structure of cell-walls. One of the questions that necessarily arises from these considerations is—how far can the protoplasm of wheat be dried out without causing loss of life in the seed? And further, when the protoplasmic contents have been dried out to certain limits, is such dried living matter more resistant to the usual destructive action of extreme cold and heat? An attempt has been made here to answer some part of these questions.

As already stated elsewhere, a number of observers, Thiselton-Dyer (1899) particularly, have shown that well-dried seeds withstand the rigours of extreme cold better than air-dried seeds. Outside the work of White (1909), experiments on wheat seeds at high temperatures do not, however, seem to have been made, and Table I shows the remarkable

TABLE I

WHEAT AFTER STORAGE FOR 10 YEARS IN DESICCATOR AND CONTAINING 1.97% MOISTURE WHEN HEATED TO 100° C. FOR VARYING PERIODS OF TIME
Original germinative power before heat-treatment 62%.

Time at 100° C.	Germination after—*hours*										
	24	48	72	96	120	144	168	192	216	240	264
2 hours	—	—	3	25	41	46	49	51	51	51	51
4 hours	—	—	—	3	26	39	42	42	42	42	42
6 hours	—	—	—	—	3	16	23	24	24	24	24
8½ hours	—	—	—	—	2	5	11	11	11	11	11

[3] *Cf.* Low mineral-content of Mummy-wheats, 3,000 years old. Whymper, 1913.

resistance of well-dried wheat (moisture, 1.97%) to the high temperature of 100° C. In this case the wheat was kept in a desiccator over calcium chloride for 10 years in the light, and the age alone had been responsible for a drop in vitality from 95% to 62% germination before the heat-treatment was made.

The sample of wheat, with which the experiments that follow were made, was kept in a closed tin in the laboratory at a fairly even temperature of 15° to 16° C. Before a sample was drawn for experiment the whole mass was well stirred, and the percentage of moisture in each sample then estimated.

Germination was conducted at 30° C. on sterilized cotton-wool soaked in sterilized distilled water.

Early experiments had shown that in a given time, with the same sample of wheat, those grains possessing the higher percentages of moisture within certain limits were the slower to germinate. This has been confirmed by the figures given by Carruthers (1911) though, curiously enough, he omitted to comment on the results he obtained from wheat and other cereals while he hastened to draw conclusions from those from many other seeds, especially the swede and the turnip. Consequently, the opinion expressed by that worker on the general problem is at variance with the results he obtained specifically with wheat, and with those reached by the present writers.

Carruthers' opinion as to the effect produced by loss of moisture under prolonged storage conditions on the germinative energy of seeds is, perhaps, best shown in his own words—

> "As to the effect of age on rapidity of germination, one would naturally expect that the older seeds would need time to regain the portion of natural moisture lost by keeping before absorbing the further moisture necessary for germination. The time required would be very small in the second year when the seed had dried but little, but would increase later. That this is so is shown by the tables. It is specially distinct in the cases where all the seeds germinated early; in the second year a small percentage lagged into the second week, and in the third year some of them were seen to lag even further behind; see, for example, green top swede and the two turnips."

Carruthers certainly intended these remarks to apply to wheat also for he only exempted five varieties of the seeds with which he experimented as "specially slow in germination" and "presumably they are those which under open-air conditions may be one or two years in the ground without germinating." In the case of wheat, at any rate, the present writers have shown that grains containing the less moisture within certain limits are the more rapid in germination, all other things being equal.

One of us in a previous paper, already mentioned, was not prepared to admit that the loss of moisture alone could account for the loss of vitality in wheat, nor, indeed, for the slowing down of germinative

energy, which had so often been stated to be the case by previous workers with other seeds that had become dry with age. Our results, shown previously, certainly indicate that, in the case of wheat, reduced moisture can both prolong life and increase germinative activity.

Duvel (1904) has made an exhaustive set of experiments on the influence of moisture and heat upon seeds in general. From these experiments he has drawn conclusions which may be summarized thus:

> Unless seeds are *thoroughly* well dried and kept in a dry room, temperatures above 30° C. are distinctly injurious. In such cases where the seeds are not truly dry, the lower the temperature that can be maintained the better the chance of longevity. A temperature just above the freezing-point of water was suggested as suitable for commercial purposes.
>
> Air-dried seeds can be kept at temperatures below the limit of 37° C. without injury, but between 38° C. and 40° C. premature death is caused.
>
> Seeds thoroughly dried in vacuo over sulphuric acid can be stored under conditions of a fairly wide range of temperature if the surrounding air be kept dry.

In contradiction to these observations, the statement of Carruthers already quoted should be compared.

The effects produced by drying seeds are many:

> Drying checks the growth of bacteria and fungi on a suitable medium such as wheat.
>
> Removal of moisture alters the equilibrium of the chemical contents of the cells and of the cells themselves in relation to one another. Once dry and in a constant temperature, there will be little or no movement of the cell-juices within the seeds; both intra- and inter-cellular chemical and enzymic action is thereby checked.
>
> Drying hardens the integument somewhat, lessening the dangers of attack by bacteria and fungi, and modifying the permeability of the seed-coat. Excessive drying is, however, apt to cause cracked seed-coats on wheat.
>
> Drying prevents excessive respiration and, therefore, undue loss of energy.

We are now in a position to consider our results obtained on heating wheat for different periods of time at different temperatures.

It may be generally concluded from results shown in Tables I to III that as the percentage of moisture present increases in the seeds the time of exposure to high temperatures must be reduced if the seeds are not to perish.

As seen from Table III, wheat heated at 70° C. for 15, 30, 45, 60, and 75 minutes showed a progressive decrease in percentage germinative energy of 10, 4, 7, 2, 2, respectively, compared with 20% for the control at the end of 48 hours germination at 30° C.; and a decrease to 30, 27, 22, 14, 19 per cent, respectively, compared with 47% germination for the control when germinated for 120 hours. These wheat grains contained 13.5% of moisture at the outset and dropped to 11.3%, 11.5%, 11.03%, 10.0%, and 9.11% at the various times of heating, namely, 15, 30, 45, 60, and 75 minutes, respectively.

Other deductions can be drawn from Table III. Seeds with low germinative power and energy at the outset (see samples m and n)

TABLE II

INFLUENCE OF MOISTURE ORIGINALLY PRESENT IN THE WHEAT SEED ON GERMINATIVE ENERGY AT 30° C.

Sample		Moisture	Per cent germination after—*hours*								
			24	40	48	64	72	89	96	113	120
		P. ct.									
A	1	15.7	—	—	—	7	10	12	15	21	—
	2	14.7	—	2	—	—	—	12	19	21	—
	3	6.7	—	2	—	—	—	27	44	57	—
B	4	5.3	—	—	23	52	67	76	85	88	—
	5	5.0	—	—	54	77	85	—	—	—	—
C	6	0.66	100	—	—	—	—	—	—	—	—
	7	0.66	3	—	43	—	71	—	—	—	82

Notes:
Nos. 3, 4, and 5. Desiccated over calcium chloride.
No. 6. 2 years old.
No. 7. 16½ years old.

appear, as might be expected, to lose their vitality more rapidly at high temperatures such as 61° and 62° C. than does wheat with a higher germinative power and energy at a still higher temperature such as 70° C. (see experiment x). Again, while heating at all temperatures from 48.5° C. to 70° C. for 45 minutes seems partially destructive to vitality, heating for a further 15 to 30 minutes does not continue to destroy vitality proportionately, but, on occasions, especially among the seeds with originally higher vitality, increases the germinative power, though such increased germinative power is slightly below that of the original unheated seeds.

Reference to Table I will show that in the case of a ten-year-old wheat, desiccated to 1.97% of moisture over calcium chloride, heating for 8½ hours to 100° C. has still not destroyed, though greatly reduced, the power of germination which dropped from 95% to 62% by age and desiccation alone and then to 11% by subsequent intense heat-treatment.

White (1909) dried wheat in a desiccator over sulphuric acid for 7 to 10 days and heated the desiccated seeds at 100° C. for 30 minutes. The drop in germinative power was to 48% compared with 100% control. Heated to 102° C. for the same time the germinative power was nil. After heating to 100° C., the diastatic activity was unimpaired but at the higher temperature was somewhat diminished. Our own figures, shown in Table I, giving the results of heating at 100° C. artificially desiccated seeds, should be compared with White's results.

At the other extreme Duvel (1904) found that air-dried seeds, maintained at about the freezing-point of water up to 167 days, and provided that the seeds were kept in sealed bottles, showed even greater ger-

minative power and energy than the original seeds. The same seeds kept in paper bags at room-temperature absorbed some moisture and showed a slight deterioration in both power and energy when germinated.

With wheat at still lower temperatures, White (1909) confirmed the results of Thiselton-Dyer (1899) that, submitted to the temperature of liquid hydrogen (— 250° C.), seeds retained their vitality unimpaired for considerable periods of time. After such low temperatures the enzymic activity was found to be in no way impaired.

de Candolle (1897), by keeping seeds under mercury, considered that he had obtained complete vital inertia because there was no apparent respiration. Kochs (1890) had previously reached the same conclusion as he did not detect any evolved gas from seeds kept for a month in vacuo: and many other workers have shown that the vitality of seeds is in no way impaired by long subjection to vacuum or immersion in various water-free liquids. In the case of wheat, however, that had been so treated over a period of ten and more years we have not been able to confirm these results, or, rather, better results have been obtained by us in securing longevity by desiccation than by completely preventing respiration.

At very low temperatures such as liquid air (— 180 to — 190° C.) Brown and Escombe (1898) concluded that all chemical action ceased and that, consequently, the protoplasmic contents of seeds submitted to such temperatures must be considered as existing in an absolutely inert state. But, until definite cases of largely increased longevity have been proved by the subjection of seeds to these low temperatures over the whole period, the process of extreme chilling must be looked upon merely as an aid to the preservation of vitality and not as the means of reaching immortality.

Wheat grains started for germination in the presence of caustic potash in sealed vessels had been shown by the present writers to germinate with greater rapidity than under normal conditions, presumably owing to the removal of the carbon dioxide as fast as it was formed. The energy of germination is still further increased when this experiment is performed under slightly reduced atmospheric pressure. It is needless to add that the presence of carbon dioxide is essential to the growth of the plant in later stages and that the above observations refer only to incipient germination.

The destructive rôle played by the presence of normal moisture in air-dried seeds, in every known case tending to devitalise the seeds in time, may largely arise from the production of inhibitants, such as carbon dioxide, or of comparatively inert compounds formed between the components of the endosperm and embryo and that gas. Such products, as Kidd (1914) has shown in the case of carbon dioxide, may materially slow down the rate of germination, if not eventually causing death.

Conclusions

Our results on heating and drying wheat seeds may be variously interpreted.

In the first place they may indicate that when both longevity and germinative energy are increased by drying at room-temperatures, movement of the cell-juices of the seed, and hence loss of energy, have been reduced to a suitable minimum without bringing about the destruction of the living protoplasm.

Secondly, it may be assumed that by drying, with or without heat, the embryo has been both chemically and physically changed. So far as increase of germinative energy is concerned, Kidd (1914) expressed the opinion that " what appears to be an act of excitatory stimulus producing a certain forward change is in reality the removal of a depressant stimulus normally present which acts as an inhibitant." Doubtless this applies to many seeds, and, since carbon dioxide has been shown by Kidd, Baker, and others to be an inhibitant to forward growth, and wheat, as we have shown, can be stimulated during germination by removal of carbon dioxide as formed, it is safe to assume that moderate desiccation by heat at any rate aids in removal of the inhibiting carbon dioxide. Our own opinion is that, in the case of wheat, exposure to carbon dioxide in high concentration, whether artificially applied or resulting from respiration, is actually destructive to the living protoplasm in the wheat embryo, and inhibiting to germination when the gas is in somewhat less concentration, through a chemico-physical modification of substances of the embryo. Some confirmation of our opinion can be found in the three following records of experiments:—(*a*) with air-dried wheat seeds embedded in wax, when any carbon dioxide evolved by slight respiration at first could not escape and resulted in death of the seeds; (*b*) decreased germinative power observed in wheat seeds kept long in deep bins when the concentration of carbon dioxide due to respiration reached a high figure; and (*c*) increased germinative energy shown by wheat seeds in an atmosphere from which carbon dioxide was removed as fast as formed.

The limit of heat that can be applied to seeds without causing death depends upon the original moisture-content of the seeds at the time of heating, the germinative energy of the seeds at the time of heating, and the duration of the application of the heat. There seems to be little reason for doubting that the seed qualifications that enable life to be maintained during heating are those preventing coagulation of albuminoids, and similar irreversible changes that result in an altered state towards permanently changed and more stable equilibrium of the seed-substances. The living matter in resting air-dried seeds is visualised as raised by normal drying to a high potential state, and, by further careful

drying (as over calcium chloride at room-temperature), to a still higher state of potential with regard to its environment. Excessive heat, by changing the state of the resting living matter, results in loss of life, or of the power of exhibiting vitality, by contributing to a state of more stable equilibrium between the seed-substances involved and between them and their environment.

In considering the figures in the first group in Table III, it will be

TABLE III

PERCENTAGE GERMINATION OF WHEAT SEEDS BEFORE AND AFTER HEATING IN HOT AIR OVEN FOR VARYING PERIODS, WITH ACCOMPANYING LOSSES IN MOISTURE DUE TO HEATING

Sample	Temperature of exposure	Moisture normal unheated samples	Date of experiment	Per cent germination after—*hours*							
				40	48	64	72	89	96	113	120
	°C.	P. ct.									
Control (original wheat unheated)											
a		14.70	Nov. 11, 1913	2	2	2	2	12	19	21	34
b		15.70	Nov. 15, "	—	—	7	10	12	15	21	—
c		15.22		—	—	—	—	—	—	—	—
d		16.25	Mar. 7, 1914	—	14	36	52	59	68	73	76
e		16.24	May 14, "	—	15	21	34	35	46	47	53
f		15.00	May 22, "	—	24	45	64	66	69	70	70
g		15.20	May 23, "	—	15	25	25	25	28	28	35
h		12.30	June 6, "	—	3	9	24	26	28	31	41
i		13.60	June 13, "	—	6	9	19	27	31	33	38
j		13.43	June 27, "	—	7	11	16	19	23	23	26
k		13.00	July 18, "	—	6	12	17	21	24	25	25
l		11.13	Aug. 15, "	—	8	27	37	38	39	40	40
m		13.23	Aug. 22, "	—	5	9	14	19	21	22	25
n		12.96	Sept. 4, "	—	6	14	18	20	23	23	24
x		13.80	Jan. 1915	—	20	27	34	37	40	42	47
Series I Samples heated for 15 minutes at temperature of exposure											
a	48.5	13.20	Nov. 11, 1913	—	—	—	—	9	10	26	28
b	50.0	13.20	Nov. 15, "	—	—	2	10	10	12	23	—
c	51.0	15.09		5	7	13	22	25	27	28	—
d	52.0	16.01	Mar. 7, 1914	—	5	19	39	42	55	67	69
e	53.0	15.07	May 14, "	—	7	10	17	19	21	22	27
f	54.0	14.36	May 22, "	—	22	25	49	52	56	57	58
g	55.0	15.00	May 23, "	—	6	11	14	14	15	15	18
h	56.0	10.00	June 6, "	—	3	6	16	21	24	26	33
i	57.0	11.24	June 13, "	—	2	5	8	10	14	17	27
j	58.0	11.28	June 27, "	—	7	11	16	17	19	20	20
k	59.0	12.35	July 18, "	—	3	8	14	15	17	18	18
l	60.0	8.78	Aug. 15, "	—	4	9	26	29	33	34	35
m	61.0	12.73	Aug. 22, "	—	1	1	4	8	9	9	9
n	62.0	12.88	Sept. 4, "	—	1	1	3	6	8	8	8
x	70.0	11.30	Jan. 1915	—	10	15	19	24	27	29	30

TABLE III—(*Continued*)

Sample	Temperature of exposure	Moisture normal unheated samples	Date of experiment	Per cent germination after—*hours*							
				40	48	64	72	89	96	113	120
	°C.	P. ct.									
			Series II								
			Samples heated for 30 minutes at temperature of exposure								
a	48.5	13.12	Nov. 11, 1913	—	—	2	2	4	4	19	19
b	50.0	12.40	Nov. 15, "	—	—	5	13	14	15	23	—
c	51.0	14.94		5	7	14	25	34	36	37	—
d	52.0	15.00	Mar. 7, 1914	—	5	17	41	44	54	61	64
e	53.0	14.10	May 14, "	—	5	11	17	19	20	20	23
f	54.0	11.62	May 22, "	—	9	10	28	37	49	51	51
g	55.0	13.13	May 23, "	—	11	17	17	17	21	21	35
h	56.0	11.60	June 6, "	—	9	17	29	33	39	40	47
i	57.0	11.30	June 13, "	—	2	5	8	10	15	23	33
j	58.0	11.20	June 27, "	—	3	7	13	15	18	18	18
k	59.0	11.00	July 18, "	—	2	7	14	16	17	17	17
l	60.0	8.84	Aug. 15, "	—	3	8	17	18	19	19	20
m	61.0	13.00	Aug. 22, "	—	—	—	6	10	12	14	14
n	62.0	12.72	Sept. 4, "	—	1	1	3	5	7	8	8
x	70.0	11.52	Jan. 1915	—	4	9	17	22	24	26	27
			Series III								
			Samples heated for 45 minutes at temperature of exposure								
a	48.5	11.97	Nov. 11, 1913	—	—	—	—	2	3	19	19
b	50.0	12.80	Nov. 15, "	—	—	7	12	16	18	27	—
c	51.0	14.88		5	8	15	25	32	34	37	—
d	52.0	14.24	Mar. 7, 1914	—	6	14	30	45	53	60	60
e	53.0	14.91	May 14, "	—	7	12	33	35	39	39	45
f	54.0	11.50	May 22, "	—	12	14	32	38	42	42	42
g	55.0	13.00	May 23, "	—	3	6	12	12	16	16	19
h	56.0	10.34	June 6, "	—	2	9	10	13	17	20	10
i	57.0	8.82	June 13, "	—	2	6	9	10	11	14	24
j	58.0	12.00	June 27, "	—	3	7	13	14	15	15	15
k	59.0	11.24	July 18, "	—	4	8	13	15	16	17	17
l	60.0	8.60	Aug. 15, "	—	4	7	14	15	16	16	16
m	61.0	11.94	Aug. 22, "	—	—	1	5	7	7	7	8
n	62.0	11.98	Sept. 4, "	—	2	2	3	5	7	7	7
x	70.0	11.03	Jan. 1915	—	7	9	14	15	19	22	22

observed that neither germinative power nor energy appears to be consistent throughout a period even so short as 1½ years for the same sample of normal air-dried wheat, tested, however, for germination in different months. The wheat used was drawn from the same bulk sample after careful and thorough mixing, and the conditions of germination—method and temperature—were identical so far as we could ensure them. The only obvious variable was the month or season of

TABLE III—(*Continued*)

Sample	Temperature of exposure	Moisture normal unheated samples	Date of experiment	Per cent germination after—*hours*							
				40	48	64	72	89	96	113	120
	°C.	P. ct.									
			Series IV								
			Samples heated for 60 minutes at temperature of exposure								
a	48.5	11.78	Nov. 11, 1913	—	—	—	—	12	20	28	30
b	50.0	10.94	Nov. 15, "	—	—	5	8	15	17	24	—
c	51.0	14.80		9	11	17	31	38	40	45	—
d	52.0	14.98	Mar. 7, 1914	—	11	25	45	50	62	66	71
e	53.0	14.07	May 14, "	—	3	9	26	30	31	32	38
f	54.0	10.90	May 22, "	—	14	22	41	46	53	54	55
g	55.0	13.00	May 23, "	—	7	13	13	13	17	17	19
h	56.0	11.02	June 6, "	—	4	10	19	23	30	33	43
i	57.0	8.19	June 13, "	—	3	9	12	20	26	29	36
j	58.0	11.43	June 27, "	—	3	6	9	10	11	11	11
k	59.0	11.24	July 18, "	—	2	7	9	11	14	15	15
l	60.0	8.00	Aug. 15, "	—	1	5	17	18	18	20	21
m	61.0	10.60	Aug. 22, "	—	—	1	3	5	7	8	8
n	62.0	10.21	Sept. 4, "	—	1	2	4	5	7	7	7
x	70.0	10.00	Jan. 1915	—	2	5	8	8	10	13	14
			Series V								
			Samples heated for 75 minutes at temperature of exposure								
a	48.5	11.30	Nov. 11, 1913	—	—	—	—	16	20	33	41
b	50.0	—	Nov. 15, "	—	—	—	—	—	—	—	—
c	51.0	—		—	—	—	—	—	—	—	—
d	52.0	14.40	Mar. 7, 1914	—	7	19	37	40	46	51	51
e	53.0	13.20	May 14, "	—	2	5	13	16	16	17	39
f	54.0	10.50	May 22, "	—	13	22	47	52	60	62	62
g	55.0	12.81	May 23, "	—	9	11	11	11	16	16	28
h	56.0	9.40	June 6, "	—	7	11	22	22	25	27	35
i	57.0	7.81	June 13, "	—	2	5	11	11	26	29	39
j	58.0	10.21	June 27, "	—	4	6	9	9	12	12	12
k	59.0	10.32	July 18, "	—	3	6	10	10	15	15	15
l	60.0	8.20	Aug. 15, "	—	1	6	19	19	20	21	21
m	61.0	10.04	Aug. 22, "	—	1	2	3	3	3	3	4
n	62.0	9.76	Sept. 4, "	—	1	1	2	4	5	5	5
x	70.0	9.11	Jan. 1915	—	2	7	2	13	16	17	18

the year during which the germination tests were made. It is not our intention here to draw any conclusions from this apparently erratic seasonal germination, but rather to indicate an interesting possibility that requires further experimental proof in the case of wheat seeds.

All living entities under naturally varying conditions, *i.e.*, in the field or in the wild state, acquire a rhythm through their life-cycles, which may well tend to become habitual from frequent repetition under

apparently similar conditions, even when those entities are removed to different conditions, at any rate for a brief period. It is less a matter of rising temperature and other changing atmospheric conditions for human beings that "in Spring a young man's fancy lightly turns to thoughts of love" than it is for many other animals that exhibit a mating instinct during that season. But it is true also that seeds respond more readily to temperatures rising towards their *optima* and to increased moisture by exhibiting a tendency towards germination, or a change from the dormant to the active state, at any time of the year when those conditions occur, than do animals respond to similar stimulation reflected in their sex-life. On the other hand, the recurring habits of any living entity, arising from periodic natural occurrences, such as the changing seasons, are not phenomenal when they do take place; and it would not be remarkable if seeds were to show germinative power and energy greater at certain seasons of the year than at others, under otherwise equal conditions of temperature and moisture. There are at least two factors that might influence germinative power and energy of resting seeds when placed under suitable and similar conditions of temperature and moisture—but at different periods of the year:—(1) periodic rhythm formed from habit and at least partially heritable, and (2) periodic rhythm controlled, also at least partially, by planetary and astral combinations themselves responsible for seasonal changes. Such considerations are, however, outside the scope of the present researches.

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THE VISCOSITY TEST [1]

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The subcommittee on the viscosity test during the past year has continued without change in personnel. However, no collaborative work was undertaken as the majority of the members of the subcommittee were satisfied with the procedure outlined in the report of last year (Cereal Chem. **10**: 494–501). This procedure was developed largely for use in the soft wheat flour trade.

While no collaborative work was undertaken the chairman has devoted considerable time and carried on considerable correspondence toward the development of a viscosimetric procedure which is adapted to a wider range in flours than is normally encountered in the soft wheat trade. Such a test should prove useful in the evaluation of new wheat varieties as well as a routine control method in the mill laboratory.

The subcommittee report of last year outlined a procedure for the preparation of the flour-water suspension as well as the technique to be followed in making the viscosity determination itself. In this report the outlined method for making the viscosity determination has been followed excepting as may be noted. This method stipulates the addition of several successive increments of normal lactic acid to the flour-water suspension and the obtaining of a viscosity reading previous to the addition of each increment of acid. The increases in viscosity resulting from the various additions of acid give information regarding the ash content and buffering capacity of the flour. The final or maximum viscosity reading gives a measure of the protein content of the flour. The outlined method calls for a flour-water suspension prepared by incorporating 20 gms. of flour (15% moisture basis) in 50 cc. of distilled water, using a mortar and pestle for mixing. The resulting paste is then diluted with a second 50 cc. of distilled water and, after adding caprylic alcohol to break any foam present, the viscosity determination itself is run immediately. It is, therefore, a "no-time" method.

Using the method on experimentally milled flours, the chairman (Bayfield, 1934) obtained certain erratic results which seemed to imply

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that insufficient time was allowed during the test for hydration of all the flour particles. In other words, variations in flour granulation influenced the test.

Granulation and the Viscosity Test

To study the effect of granulation upon viscosity an unbleached bread flour was obtained and divided into three portions. Two portions were then run through the experimental mill until one sample all passed through a No. 18 silk, while the second was further reduced until it all passed through a No. 24 silk. Thus three samples of flour of varying granulation resulted. These samples contained 12.2% protein and 0.47% ash. Each flour was now subjected to the viscosity test with and without a preliminary one hour's digestion of the flour-water suspension at room temperature (80–85° F.). The results are given in Table I.

TABLE I

THE EFFECT OF FLOUR GRANULATION UPON VISCOSITY

	Viscosity in degrees MacMichael					
	Without preliminary digestion			After 1 hour digestion (room temp.)		
Amount N lactic acid used	Bread flour	Flour through No. 18 silk	Flour through No. 24 silk	Bread flour	Flour through No. 18 silk	Flour through No. 24 silk
Cc.						
0	12	14	16	11	13	15
1	19	18	19	41	38	30
3	56	61	63	112	112	108
5	83	89	101	134	135	132
7	96	101	112	143	143	141
9	101	108	116	144	144	142

It will be observed in Table I that varying the granulation of the flour produces significant differences in the viscosity readings, particularly when no preliminary digestion of the flour-water suspension was used. It was also found that the "digested" samples gave more clear-cut readings, *i.e.*, the viscosimeter bob reached a stable end point rapidly. With some samples of flour the "no time" procedure gives an unstable reading, the bob either "creeping" forward or "drifting" backward slowly.

The above tests were made at room temperature and minor variations obtained in further tests indicated that temperature control was desirable. Accordingly a water bath was used throughout the remainder of the work. This bath was electrically heated and controlled, with a temperature variation of less than $\pm$ 1° C.

Effect of Temperature on the Viscosity Test

In studying the effect of varying temperatures, flour sample No. 9, held in cold storage for over a year, was used. Storage of this sample produced a small increase in the magnitudes of viscosity readings (8–9° MacM. in maximum viscosity). Temperatures below room temperature were obtained by the use of ice in the water bath or through the use of cold water from the tap. Both the no-time and 1 hour digestion methods were used. The results are presented in Table II.

TABLE II

EFFECT OF TEMPERATURE UPON THE VISCOSITY TEST

Amount N lactic acid used	Viscosity in degrees MacMichael: No-time method (temp. ° C.)					One hour digestion (temp. ° C.)				
	1°	10°	20°	30°	40°	1°	10°	20°	30°	40°
Cc.										
0	12	12	13	13	11	14	13	9	8	9
1	75	72	64	58	55	91	89	83	72	68
3	103	101	92	89	87	126	126	122	106	105
5	107	105	96	94	94	131	131	130	115	113
7	104	102	95	93	95	127	130	131	118	116
9	100	98	92	—	—	123	126	128	116	115

Considerable trouble was experienced in obtaining satisfactory checks at the two lowest temperatures employed. The least trouble was experienced with the 30° Centigrade samples, which temperature is not far from a normal summer temperature for the laboratory. As it is easier to hold the sample temperature somewhat above room temperature rather than slightly below, it was decided to employ 30° C. (86° F.) as the standard. Furthermore, small temperature variations at this point seem to effect the viscosity results less than at lower temperatures.

Effect of Time of Digestion

In order to determine the optimum time for digestion of the flour-water suspension, a low protein (8.6%), low ash (0.33%), commercially milled flour was compared with a high protein (13.9%), moderate ash (0.43%), experimentally milled flour. Both flours were from soft red winter wheats. In the latter case insufficient flour was available to complete the entire series. The results from these tests are presented in Table III. In these tests practically no trouble was experienced from unstable viscosity readings at one hour or over. These tests were all made at 30° C.

The data in Table III indicate that the greatest amount of change in

TABLE III

EFFECT OF TIME OF DIGESTION UPON THE VISCOSITY TEST

Amount N lactic acid used	Viscosity in degrees MacMichael—Low protein flour							
	Digestion time in minutes							
	0	15	30	45	60	75	90	105
Cc.								
0	12	10	7	6	6	6	6	6
1	31	34	37	41	40	41	44	45
3	47	54	59	62	64	65	66	67
5	50	60	66	68	71	72	74	74
7	50	62	68	73	74	74	76	75
9	—	62	68	72	75	73	76	75
	Viscosity in degrees MacMichael—High protein flour							
0	20	18	18	16	15	16		
1	35	60	70	77	79	81		
3	135	152	163	185	190	195	No	No
5	161	173	188	211	213	214	flour	flour
7	168	178	192	216	217	217		
9	168	176	192	213	216	215		

viscosity due to digestion of the flour-water suspension occurs inside of the first 30 minutes. After one hour but little change occurs. As any procedure that is very sensitive to small variations in time intervals has definite disadvantages for routine laboratory work, 60 minutes as a standard time for digestion was selected.

Machine versus Hand Mixed Suspensions

One of the drawbacks in mixing the flour-water suspensions by hand in a mortar and pestle lies in the difficulty of standardizing the method between different laboratories. Another trouble is the variable number of lumps present in some suspensions. In some suspensions considerably more mixing is required than in others if freedom from lumps is to result. Varying the mixing procedure produces variations in the amount of gluten development and amount of foam produced. The chairman (Bayfield, 1932) has used a mechanical method satisfactorily for mixing whole wheat meal suspensions; and, in personal communications, G. L. Alexander and E. E. Smith reported the use of a malted milk mixer and a power egg beater, respectively, for making flour-water suspensions, the latter machine being but indifferently successful.

An old style Hamilton-Beach mixer in the laboratory, equipped with a three-quarter inch wide hexagonal mixer button, was used in preliminary tests and gave satisfactory results when a mixing time of 15 seconds was used. Of the various methods employed the most satisfactory results were obtained from the use of 50 cc. of water in a

150 cc. beaker. The flour was poured on top of the water in the beaker and dispersion during mixing was aided through the use of a stirring rod. The second 50 cc. of water was used to wash off the mixer button, the rinsings being incorporated in the suspension. While 15 seconds mixing time produced more foam than by the mortar and pestle method the extra foam was readily broken down by using caprylic alcohol. More uniform suspensions resulted from the machine mixings and the number of samples requiring rechecking was materially reduced. However, it is questionable whether a machine mixing method can be obtained which will give results identical with those obtained by hand mixing when a no-time method is used. With the digestion period preceding the viscosity determination these differences largely disappear, however, and the mechanical method is superior to the old hand-mixing method.

Five flours of widely different characteristics were employed in testing out the machine method of mixing. Pertinent data regarding these flours and the viscosity results obtained on them are given in Table IV. All of these flours were unbleached.

TABLE IV

A Comparison of Three Viscosimetric Procedures[1]

Sample No.	10			11			12			13			14		
Wheat used	H.R.S.[2] & S.R.W.[3]			White winter			S.R.W.			S.R.W.			S.R.W.		
Flour grade	Straight			Straight			Straight			Patent			Clear[5]		
Use of flour	Bread			Special pastry			Sweet goods			Cake[4]			?		
Protein in flour (%)	11.7			8.3			9.6			9.3			10.2		
Ash in flour (%)	0.46			0.42			0.47			0.31			0.51		
Viscosity procedure	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Viscosity with															
0 cc. acid	11	12	12	9	10	7	9	10	8	14	18	9	11	12	12
1 cc. acid	13	14	65	12	12	23	11	10	40	68	74	77	52–23[6]	40–16[6]	26
3 cc. acid	57	69	133	23	24	36	31	35	67	88	91	104	11	12	63
5 cc. acid	85	99	150	26	27	41	43	48	74	90	91	107	23	27	74
7 cc. acid	99	112	158	27	28	42	48	52	75	89	88	107	35	41	78
9 cc. acid	103	112	157	27	27	41	49	53	74	86	—	105	43	49	79
11 cc. acid	—	—	—	—	—	—	—	—	—	—	—	—	49	51	78

[1] Procedure A. Samples mixed in mortar and pestle, no-time method. B. Samples mechanically mixed for 15 seconds, no-time method. C. Samples mechanically mixed for 15 seconds, suspensions digested for 1 hour at 30° C.
[2] Hard red spring.
[3] Soft red winter.
[4] After suitable bleaching.
[5] Obtained during milling of sample 13.
[6] Variation in reading due to drifting from upper to lower reading.

The data in Table IV indicate that 15 seconds with this particular mixer gave somewhat higher results than hand-mixing when a no-time method was used. However, preliminary tests indicated that less than 15 seconds of mechanical mixing did not eliminate lumps from some samples. The behavior of sample 14 with the no-time method is an extreme example of drifting, it being practically impossible to determine the reading with the 1 cc. increment of acid. Such unstable readings are most frequently associated with the high ash flours. Table IV indicates that the discrepancy between the two no-time methods is influenced by both ash and protein in the sample. Probably differences in granulation also produce some of the variation.

Effect of Ash Upon the Viscosity Test

Workers for a long time have recognized that the protein test tells nothing about the quality of a flour or wheat protein. That there are decided differences in protein quality is a well known fact. In the case of ash it appears that but little attention has been given to possible changes in flour quality due to varying chemical composition of the ash in the flour. Composite samples of both flour and bran ash from the 1933 crop were obtained. Suspensions of these two ashes were prepared and added in varying amounts to flour sample 13. In these tests 20 gms. of flour (moisture-free basis) were used; they were mechanically mixed for 15 seconds, and digested for one hour at 30° C. before determining the viscosity. While varying amounts of ash were used it must be pointed out that all of this ash did not go into solution. Actually, therefore, the amount of added ash which was *effective* is less than given in Table V.

TABLE V

EFFECT OF ADDED ASH UPON VISCOSITY
(Flour No. 13, ash 0.31%)

Per cent ash added	0	.10		.20		.30		.40		.50		.60		.70	
Kind of ash[1]	Natural	F	B	F	B	F	B	F	B	F	B	F	B	F	B
Viscosity with															
0 cc. acid	14	14	14	14	14	15	15	15	17	16	17	16	—	17	17
1 cc. acid	101	82	78	68	68	52	56	44	48	36	41	31	—	28	29
3 cc. acid	142	129	119	115	104	99	91	88	79	75	72	65	—	57	54
5 cc. acid	147	136	123	122	104	106	88	94	76	81	64	70	—	62	50
7 cc. acid	147	136	125	122	105	107	86	93	73	81	61	70	—	61	45
9 cc. acid	145	132	124	119	104	105	85	—	73	80	61	68	—	60	43

[1] "F" refers to flour ash, "B" to bran ash.

The data in Table V illustrate the rapid drop in viscosity which occurs with increasing ash content. It also shows that bran ash produces a greater decrease than the ash from flour. Additions of more than .20% of bran ash gave a maximum viscosity with 3 cc. of lactic acid, whereas twice this amount of flour ash gave a maximum viscosity with 5 cc. of acid. Further work will be required to see if the same effects can be produced by using soluble leached material from bran and flour respectively. Rich (1932) has shown that bran powder and concentrated water extract of bran when added to flour-water suspensions produced similar reductions in viscosity. This preliminary experiment does indicate that more attention should be given to composition of ash instead of merely emphasizing the quantity factor alone as is done at present. While it appears that the baking test is less sensitive to ash variations than is the viscosity test, yet some of the unexplainable baking results may be due to variations in the composition of the ash in the flour. Investigations at present in progress at the Ohio Station may throw some light on this matter.

Effect of Protein Upon the Viscosity Test

The test as at present carried out utilizes a definite amount of flour. With this method a variable amount of protein is present in the samples, the amount depending upon the percentage protein in the flour. The viscosity reading, accordingly, is influenced by both the quantity and quality of protein in the sample. In the past some workers have attempted to eliminate the *quantity* of protein factor by weighing out each flour sample so that it contained a definite amount of protein. Alexander (1932) has found such a method very useful in evaluating certain types of soft wheat flours.

A few experimentally milled flours were selected for testing the uniform protein method. These flours were milled from wheat of the same variety grown under identical climatic conditions. The method followed was to weigh out sufficient flour to equal 2 gms. of protein, mix mechanically for 15 seconds, digest for one hour at 30° C., and determine the viscosity using the usual procedure. The viscosity was also determined on the same samples using 20 gms. (15% moisture basis) of flour and by a third method whereby sufficient wheat starch was added to uniform protein samples so that the same bulk of material was present in each case. This latter method was tried out in view of the fact that the extra starch present in low protein samples (when using the uniform protein method), as compared with high protein samples, would remove a certain amount of water out of the colloidal flour-water suspension system. This, it was thought, would possibly

produce some changes in the viscosity readings. The sample of starch "B" contained 0.30% protein and 0.19% ash. Twenty grams of this sample in 100 cc. of distilled water gave a viscosity reading of 6° MacM. before acidulation and 3° MacM. with 7 cc. of lactic acid. It was prepared from a bread flour. Starch sample C was obtained on the market. Its viscosity was 2° MacM. both before and after acidulation. Starch "C" contained 0.30% protein and 0.303% ash. Both samples of starch were used in tests on a second series of wheat flours. Viscosity and other data for these samples are presented in Table VI.

From Table VI the following conclusions may be drawn:

(*a*) When the weight of flour in the sample is held constant the viscosity tends to increase with amount of protein present.

(*b*) When the weight of protein in the sample is held constant and the weight of sample varies much less variation occurs in the viscosity in these samples. In Series 1 there appears to be a tendency toward a decrease in maximum viscosity as the weight of flour used decreased, *i.e.*, as the percentage of protein in the flour sample increased. However, in Series 2 this tendency is reversed. The difference in behavior between the two series may be due to season but more probably to ash content. Variations within the series apparently are due to either (1) actual differences in gluten quality or (2) variations in amount and composition of the ash in the sample.

(*c*) When the weight of protein and total bulk of sample are held constant by adding the low ash wheat starch (B) the viscosity is increased over the sample run without starch. This increase is relatively greater as the percentage protein in the flour increased. In other words, the additional starch, present in the larger sized sample required in order to obtain 2 grams of protein from a low protein flour, does increase the viscosity to some extent.

(*d*) When the higher ash commercial wheat starch (C) is used instead of starch B the viscosity is reduced in each case below the sample run without starch. The depression due to starch C becomes slightly less as the protein percentage in the flour increased but this increase in viscosity may be due to the fact that the concentration of ash in the suspension decreases in this series as the amount of added starch increased.

To summarize the results of these preliminary tests we may conclude that in order to use the constant protein method as a measure for gluten quality it will be necessary to hold the ash content as constant as possible. Further, it would appear that the use of added starch to the sample is an improvement, provided a suitable low ash starch is available. For routine laboratory purposes, however, it is questionable whether this added refinement is justifiable. While only one variety has been con-

TABLE VI

VISCOSITY DATA[1] FROM CONSTANT PROTEIN SAMPLES VS. CONSTANT WEIGHT OF FLOUR SAMPLES

Series 1—Crop of 1932

Sample no.	1653		1654			1658			1643			1657		
Protein in flour—*P.ct.*[2]	8.44		9.44			10.08			11.72			12.96		
Ash in flour—*P.ct.*[2]	0.42		0.43			0.42			0.43			0.50		
Weight flour used—*Gms.*	23.7	20.0	21.2	21.2	20.0	19.8	19.8	20.0	17.1	17.1	20.0	15.4	15.4	20.0
Weight added starch—*Gms.*[3]	0	0	0	2.5	0	0	3.9	0	0	6.6	0	0	8.3	0
Viscosity, no acid	13	8	12	14	10	11	15	11	9	13	14	8	13	16
" , 1 cc. acid	49	38	55	61	52	51	60	52	56	68	67	47	63	64
" , 3 cc. "	98	63	101	107	87	87	100	88	97	113	125	82	107	135
" , 5 cc. "	111	72	111	121	94	100	111	99	107	125	138	93	121	151
" , 7 cc. "	119	74	115	124	97	103	115	103	110	127	143	97	123	156

Series 2—Crop of 1933

Sample no.	2227		2213				2211				2220			
Protein in flour—*P.ct.*[2]	8.08		9.04				10.68				11.52			
Ash in flour—*P.ct.*[2]	0.44		0.44				0.43				0.43			
Weight flour used—*Gms.*	24.8	20.0	22.1	22.1	22.1	20.0	18.8	18.8	18.8	20.0	17.4	17.4	17.4	20.0
Weight added starch—*Gms.*	0	0	0	2.7	2.7	0	0	6.0	6.0	0	0	7.4	7.4	0
Starch used	—	—	—	B	C	—	—	B	C	—	—	B	C	—
Viscosity, no acid	17	10	15	17	15	11	10	14	11	11	10	14	11	12
" , 1 cc. acid	42	34	46	49	26	43	65	72	45	65	60	70	43	64
" , 3 cc. "	85	58	90	95	67	75	106	119	87	112	100	118	83	117
" , 5 cc. "	95	63	101	108	78	82	114	129	95	120	105	126	92	126
" , 7 cc. "	99	65	104	111	81	85	115	131	97	122	106	127	93	128

[1] Viscosity data in ° MacMichael.
[2] Protein and ash percentages not corrected for moisture.
[3] Starch B used in Series 1.

sidered in these studies it does appear as though the constant protein method is worthy of further trial as a quality measure. The constant flour weight method gives results which are definitely correlated with the quantity of protein in the sample. Further comparisons of the two methods will be presented in a later paper.

Comparison of Mixing Machines

All of the tests reported on were made with an old style Hamilton-Beach mixer. This particular model is no longer being produced. It seemed desirable to compare a more modern make of machine against its predecessor. Accordingly, a No. 18 Mixer made by the same company was procured. This is a two-speed mixer. The low speed produced a suitable incorporation of the flour. However, the machine should be equipped with the hexagonal solid type of mixer button rather than the newer type button which makes more foam than is necessary. Unfortunately, lack of time prevented any very extensive comparison of the various machines on the market at the present time.

Summary

Several factors which affect the results obtained in making a viscosity determination on a flour-water suspension have been investigated. It is hoped that these results may prove useful in the further evolution of the viscosity test.

Flour granulation was found to have a decided influence upon the test, particularly when no time is allowed for flour hydration between making up the suspension and running the determination. Increasing fineness of flour increased the maximum viscosity in these "no-time" tests. Digesting the suspension for one hour largely eliminated the influence of varying flour granulation.

From a series of tests when time and temperature of digestion were varied it was concluded that one hour and 30° C. gave satisfactory results. It seems desirable to use such a digestion period in cases where a wide range in flour characteristics is expected to be encountered or in cases where protein quality alone is being determined.

Machine mixing of the flour-water suspension was found to give more uniform results than hand mixing in a mortar and pestle. Machine mixing was less desirable where a no-time method was employed.

Addition of varying amounts of bran and flour ash to a low ash flour indicated that the composition, as well as the quantity, of ash affects the viscosity results.

Tests were carried out comparing the use of a constant amount of protein in the sample with the use of a constant flour weight sample.

Results indicate that variable amounts of protein in a sample (constant flour weight) produce large differences in the viscosity results. The use of a constant weight of protein in the sample largely eliminates these differences when one variety of wheat is used. Provided that ash content is held within narrow limits, the use of a constant weight of protein sample gives promise of giving a measure of protein quality. Further work is necessary regarding this point.

Acknowledgements

The chairman wishes to express his appreciation to the various members of the subcommittee for supplying him with needed flours and information regarding them. It has been a constant source of pleasure for him to work with such an enterprising group of chemists.

Acknowledgment of appreciation is also made to the Hamilton-Beach Manufacturing Company, Racine, Wisconsin, for the loan of their newest model mixer for test purposes.

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A SURVEY OF TEST BAKING PROCEDURES EMPLOYED IN AMERICA[1, 2]

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(Presented at the Annual Meeting, June, 1934)

In 1924, Fitz circulated a questionnaire to a large number of well known cereal laboratories for the purpose of obtaining, among other things, detailed information as to the types of test baking procedures in general use. At that time no published reference had been made to any 100-gram flour dough procedure and it was not until the following year that Werner (1925) brought this method to the attention of cereal chemists. From the replies received, Fitz concluded

"that very few laboratories are using anything like the same formula, method of procedure, or type and style of pan. It is possible that still wider variations might be shown if additional questionnaires were sent out. However, it seems that we have enough data at hand to bring the matter before the association and to suggest that a committee be appointed to investigate the possibility and the desirability of working out a standard or official method for baking tests which could be used as a means of checking results between laboratories."

In his capacity as chairman of the Committee on Standardization of the Experimental Baking Test of the A. A. C. C., Blish (1927) again referred to the need for standardizing experimental baking and recommended that a fixed type of procedure be tentatively adopted for testing the baking quality of flour, or at least its fermentation tolerance. This recommendation was followed by a questionnaire which Blish (1927a) circulated to the membership "to ascertain, in a general way, the modern attitude of cereal chemists as to various important aspects of the laboratory baking test." Of the 140 persons from whom replies were received, approximately 33% stated that the individual was satisfied with his present method, 20% were only partly so, while the remainder were, in general, dissatisfied. There was a decided preponderance of opinion that the development of a satisfactory standard procedure was possible and that it should be attempted. From this investigation, Blish concluded "that the questionnaire served merely to emphasize and substantiate the findings of Fitz (1924)."

Blish (1928) outlined a definite fixed baking procedure based upon

[1] Subcommittee report, 1933–34 Committee on the Standardization of Laboratory Baking.
[2] Issued as Paper No. 8, Grain Research Laboratory, Board of Grain Commissioners for Canada.

the principles previously established (Blish 1927), which had been approved as a tentative method and published as a standard laboratory baking procedure.

Harrel (1928) introduced several supplementary procedures which were approved, and four years later Merritt, Blish, and Sandstedt (1932) suggested a number of additional supplements, at the same time recommending:

"that mention of additional and supplementary tests should either be deleted from the written specifications of the standard experimental baking test or, if this is not done, the number should be increased to include many others that are just as rational, informative and permissible as are the four that are now specified in the present standard experimental baking test."

From this brief review it will be seen that two questionnaires have been submitted to cereal chemists on this continent, both prior to the adoption of any fixed baking procedure. It, therefore, seemed desirable to circulate a third one to obtain details of the baking methods now in general use and the extent to which the basic and supplementary procedures are applied, as it is some six years since the basic formula was published and four years since the original supplements were introduced.

In order to ascertain this information, a questionnaire was circulated among the members of the American Association of Cereal Chemists in the United States and Canada in April 1934, containing 12 questions pertaining to the merits of the 100-gram and commercial-type loaves, the baking methods employed, the value of the standard basic test and the supplementary procedures in favour. Opinions were also solicited as to the value of any "pup" loaf baking method for determining the behaviour of a flour under commercial conditions; whether the efforts of the Baking Test Committee in developing the standard baking procedure have been justified; and suggestions for future investigations to be undertaken by the committee. Owing to the limited time available for the preparation of a report in time for the Toronto meeting, it became necessary to include only those replies which were received on or before May 15.

Of the 297 members to whom questionnaires were sent, 85 returned them completed or supplied the information in some other form in time to be used in the survey, while 20 advised that they did not conduct a sufficient number of baking tests to warrant making any statement. Since in several of the laboratories more than one chemist is connected with experimental baking, the replies received actually represent the opinions of 181 chemists. In view of the fact that those circularized included members associated with commercial mills, commercial baking organizations, plant breeding stations or research institutions, the information at hand may be considered as being very representative of

TABLE I

100-GRAM FLOUR DOUGH FORMULAS AND PROCEDURES IN COMMON USE, WHICH DIFFER FROM THE STANDARD BASIC PROCEDURE

Number of chemists represented	Ref. no.	Yeast	Salt	Sugar	Other ingredients	Water absorption	Mixer	Mixing time	Ferm. time	Ferm. temp.	Number of punches	Baking pan dimensions			Proving		Baking		Time after baking when loaf measured	Tolerance between replicate loaves
												Top	Bottom	Depth	Time	Temp.	Time	Temp.		
		Gm.	*Gm.*	*Gm.*	*Gm.*	%		*Min.*	*Hr.*	° *C.*		*Cm.*	*Cm.*	*Cm.*	*Min.*	° *C.*	*Min.*	° *C.*	*Min.*	*Cc.*
2	1	3	1	2½	½ to 3 diastatic flour	Variable	Hobart-Swanson and Bachman	Variable	3	29.5	2	Standard high type			Generally 55	29.5	25	230	5–60	15–25
1	2	3	1	3	—	Variable	Hobart	2	2	30	1	Standard high type			55	30	25	230	30	20
1	3	3	1	2½	Varying amounts $KBrO_3$ and diastatic malt plus 0.1 $NH_4H_2PO_4$	Variable	Hobart-Swanson	1	3	30	—	7 × 11.5	5.3 × 9.2	5.3	55	30	25	230	30	30
2	4	3	1	2½	Sometimes $KBrO_3$	Variable	Hobart	2	3	30	2	Standard high type			60	30	25	230	45	—
1	5	3	2	2½	Various increments $KBrO_3$ or Malt	Variable	Hand	2	3	30	3	6.3 × 10	4.3 × 7.5	4	55	30	25	215	15	25
1	6	3	1¼	2½	Shortening 2	Variable	General Mills	2¼	3–20″	28	3	6 × 10.5	5.3 × 9.3	6.8	Fixed	28	25	230	60	15
5	7	3	1	2½	Shortening 2	Variable	Kitchen-Aid	1	3	28	3	Standard high type			60	28	25	232	30	—
6	8	3	1	2½	Shortening 2	Variable	Machine	1¼	3	28	2	—	—	—	Variable	28	25	230	30	30
1	9	2	1¼	4	Shortening 2	Variable	Hobart	2	2–30″	28	1	6.5 × 11.7	4.8 × 9	8.8	To top of pan	28	20	230	—	—
2	10	3	1	5	—	Variable	Hand	3½	3	30	3	5.5 × 10.5	5.3 × 9.3	8.5	55	30	25	230	30	20
3	11	3	1	Variable	Variable $KBrO_3$	Variable	Hobart	3	Variable	30	3	Standard high type			To definite height	30	25	230	30	10–15
2	12	4½	1½	4½	Shortening 3.3, Arkady 0.3	Variable	Hobart	4	2–55″	30	2	11.5 × 24	8.5 × 21.5	7.5	Variable	32.1	30	200	Immediately	30

TABLE I—(*Continued*)

Number of chemists represented	Ref. no.	Yeast	Salt	Sugar	Other ingredients	Water absorption	Mixer	Mixing time	Ferm. time	Ferm. temp.	Number of punches	Baking pan dimensions			Proving		Baking		Time after baking when loaf measured	Tolerance between replicate loaves
												Top	Bottom	Depth	Time	Temp.	Time	Temp.		
		Gm.	*Gm.*	*Gm.*	*Gm.*	%		*Min.*	*Hr.*	° *C.*		*Cm.*	*Cm.*	*Cm.*	*Min.*	° *C.*	*Min.*	° *C.*	*Min.*	*Cc.*
1	13	3	1	2½	Shortening 2	Variable	Hobart	1¾	3	28	3	6 × 10.5	5.3 × 9.3	8.5	70	28	25	232	30	15
1	14	3	1	0–2½	$KBrO_3$ .001 and .002	Variable	Hobart	2 & 4	3 & 4	28	2	Standard high type			Variable	28	25	232	When cool	20
1	15	3	1	0–2½	Yeast food; Malted wheat flour	Variable	Hobart	2	1 to 4	Variable	0–3	7.5 × 12.5	5.3 × 9.2	5.2	Variable	Variable	25	230	—	—
2	16	3	1	2½	—	Variable	Hobart-Swanson	1	3	30	3	6.5 × 10.5	3 × 9	7 (sides 8.5)	To about top of pan	30	30	230	60	20
2	17	3	1	2½	—	Variable	Hobart	3½	A.A	.C.C.		Standard high type			A.A.C.C.		25	230	60	—
1	18	3	1	3	—	Variable	Modified Fleischmann	1½	3	30	2	6 × 10.5	5.3 × 9.5	6.8	55	30	25	230	30	20
3	19	3	1	5	—	Variable	Kitchen-Aid	2½	3	30	2	6 × 10.5	5.3 × 9.3	6.8 (sides 8.5)	55	30	30	230	30	20
3	20	3	1	Variable	Some used but not specified	Variable	Fleischmann	3	Variable	30	None	6.1 × 10.6	5.3 × 9.3	8.6	To top of pan	30	30	210	90–120	—
3	21	3	1	2½	Various supplements in certain studies	Variable	Kitchen-Aid	1½	3	29	2	5.7 × 10.8	4.4 × 8.9	7.6	55	29	25	215	15	10
1	22	3	1	2½	—	Variable	Hobart	2	3	30	2	6 × 10.5	5.3 × 9.3	6.8 (sides 8.5)	55	30	25	224	30	—
4	23	3	1	2½	—	Variable	Hobart	3	3	30	2	6.9 × 10.6	5.4 × 9.2	5	55	30	25	220	30	30
2	24	3	1½	3½	—	60	Hobart-Swanson	1	2–40	—	—	Standard A.A.C.C.			55	—	25	232	Immediately	25
1	25	3	1	2½	Arkady	Variable	Hobart	4	1–50	30	2	6.9 × 11.4	4.9 × 8.9	5.2	Fixed	30	30	220	60	25

cereal chemists in the United States and Canada. It is regretted that details of the "pup" loaf baking procedures used, which vary in some form from the standard basic procedure, were not given in very many instances, since this information would have permitted a more comprehensive study of the methods, but what information is at hand is given in detail in Table I.

A study of the replies shows that 13% of the laboratories which reported use the basic procedure exactly as specified in Cereal Chemistry, Vol. 5: 158–161, 5% employ this method with either variable absorption or machine mixing, and 22% some modified or supplementary "pup" loaf procedure. Forty-nine per cent prefer the commercial type of test loaf, while 8% use both the commercial and one or other "pup" loaf method. Of the 13% using the basic procedure, 7% employ a commercial type of loaf for control purposes. In general, it may be said that the commercial loaf is favoured in laboratories associated with the larger mills and baking organizations. From the daily production figures furnished by mill chemists, it appears that one or other "pup" loaf procedure is in use for the day-to-day control of approximately 76,000 barrels of flour, while the commercial type of loaf serves to control nearly 130,000 barrels.

Forty-one per cent of the organizations now using a commercial test loaf have tried certain or all of the "pup" loaf baking procedures recommended, while 12% in this class have never used any other form. In 15% of the laboratories, some form of "pup" loaf has replaced a commercial type previously in use, while only one chemist reports having returned to the latter after using "pup" loaf procedures. Those now using a commercial loaf and who have tried the basic or supplementary procedures, prefer the former for a number of reasons, some examples being: (1) that the commercial type of test loaf closely corresponds with that produced commercially, hence it is more easily understood by the non-technical members of the staff; (2) that the larger dough is better in indicating the absorption, and produces a loaf which is more suitable for judging internal and external characteristics; and (3) that the larger dough is less subject to variations due to uncontrollable temperature changes and to handling.

There was fairly good agreement that certain "pup" loaf procedures indicate the behaviour of a flour under commercial bake-shop conditions, provided suitable formulas are employed and the results are correctly interpreted; in fact, only about 11% emphatically stated or were in doubt, that this is not possible.

A study of the 100-gram flour dough formulas submitted shows that in only a comparatively small number of the cases is the routine test

carried out in exactly the same manner; different formulas, mixing machines, baking pans and ovens being employed, also various mixing and fermentation times. Proving is sometimes done to a fixed or variable time and sometimes to a fixed or variable height. Although the dimensions of the baking pans vary, the tall form appears to be used the most. There is a very fair degree of agreement as to the quantities of certain basic ingredients used, namely, yeast 3 gms., sugar 2½ gms., and salt 1 gm., but other ingredients, *i.e.* shortening, malt, and bromate, are added in some cases. In almost every case the absorption is varied to suit the requirements of the flour, and mixing the dough by hand was seldom mentioned.

The general consensus of opinion was that the work of the Baking Test Committee in developing a standard basic procedure and other related tests has been fully justified by the results obtained, and many of the chemists not at present baking a 100-gram flour dough agreed that much valuable information regarding experimental baking in general has been made available as a result of the efforts of the committee.

The response to suggestions for future investigations of the Baking Test Committee was excellent, some of which follow: (*a*) the effect of proving to a fixed height instead of to a definite time, (*b*) the relationship between commercial and experimental results when corresponding flours are baked under commercial bake-shop and laboratory conditions, (*c*) the proper interpretation of the results with the basic and supplementary procedures now recommended, (*d*) the development of a straight and sponge dough formula, using the commercial type of loaf, (*e*) the effect on the baking quality of variations due to humidity and atmospheric pressure, and (*f*) the effect of baking pans of different dimensions and composition.

From the present survey there seems to be much greater uniformity in the test baking methods employed than was shown by the replies to the previous questionnaires referred to, but there is admittedly still room for improvement. Since the standard basic procedure is seldom used in its present form, it appears highly desirable to revise the method and, in the light of present knowledge, hand mixing to a fixed absorption should be abandoned.

It is of interest to mention that within the past few years a distinct advance in the uniformity of experimental baking methods has been made by the Canadian members of the association, and reference to recent literature shows that certain "pup" loaf procedures have been adopted not only by workers in research institutions but also by the commercial chemist. This uniformity in the methods is a step in the right direction and indicates that the endeavour to develop and en-

courage the use of certain standard baking procedures over a much wider field should be continued.

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FLOUR PARTICLE SIZE BY THE SEDIMENTATION METHOD [1]

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(Presented at the Annual Meeting, June, 1934)

The customary method of determining flour particle size has been by the use of silk sieves of standard mesh shaken for some definite period of time in some form of a laboratory sifter. This test has been recognized for some years to have very serious disadvantages. Shollenberger and Coleman (1926) found that finely ground flour bolted more slowly than more coarsely ground flour. Van der Lee (1928) considered the electrical forces generated by the rubbing of the stock over the silk sieves to be a factor in the determination. Berliner and Rüter (1928) found clumping of the flour particles to interfere with bolting. Micka and Vrana (1930) found that the temperature and moisture content of the flour, the temperature and humidity of the air, the motion of the sifter, and the relative loading of the sieves with flour all affected the results of a sifting test for granulation. They recommended that not only the amount of stock passing a given sieve in a given time be reported, but that also the rate of bolting should be included in the report. Gründer (1932) pointed out that with the use of the finest silk

[1] Published with the approval of the Director as Paper No. 1278, Journal Series, Minnesota Agricultural Experiment Station.

ordinarily available (25XX) there could be no differentiation of particles of less than 60 μ in diameter.

Other possible methods of determining particle size are direct measurement, air separation, and sedimentation. Direct measurement by means of a special microscope is slow and tedious. Air separation methods are used on a large scale in commercial milling practise, but have proven very difficult to control in small scale laboratory equipment. Sedimentation methods have proven to be perhaps the most precise of all methods of determining particle size.

Odén (1916) worked out a very accurate method of determining the particle size of soils. His method was to suspend one pan of a balance in a dilute suspension of the soil in water and note the increase in weight of the pan as the particles settled out. He found the rate of sedimentation with his apparatus to approximate Stokes' Law of Falling Spheres in a Liquid, which is—

$$v = 2/9gr^2\frac{D - D_1}{n}, \qquad \text{(I)}$$

where v = velocity of fall, g = gravity constant, r = equivalent radius, D = density of particle, D_1 = density of medium, n = viscosity of medium.

Gründer (1932–1934) applied a variant of Odén's technic to flour granulation studies. Since in such a test the particles and medium must be in lyophobic relation to each other, water was not suitable. He found " Palatinol A " (the di-ethyl ester of phthalic acid) to be a suitable solvent. However, there appeared to be some disturbing force at work in the early stages of Gründer's method since he found a lag before the maximum rate of sedimentation commenced. According to Stokes' Law in such a system the maximum rate of sedimentation should be at the moment of starting to settle out. The difficulty probably lay in that the high viscosity medium trapped air when shaken up which produced counter currents upward in the suspension and delayed sedimentation.

Graphical representations of the relative particle sizes of various systems can be shown by plotting per cent deposited against time, as in Figure 1. According to Stokes' Law, since in a definite system $v = h/t$, where h = height of fall, and t = time of fall, all particles of a radius larger than

$$r = \sqrt{\frac{9hn}{2t(D - D_1)}}$$

at time t, have been deposited, so in any one system the radius of the largest particle being deposited at a given time is in inverse ratio to that time. Odén (1916) represented a graphical method of determining the

size distribution from the per cent deposited-time curve. He drew tangents to the curves at successive time intervals, as shown in Figure 1, and the points where these tangents intersected the per cent deposited axis were found by him to represent the amount of particles in the system with radii larger than those defined by the time points used.

Knapp (1934) placed Odén's graphical method upon a sound mathe-

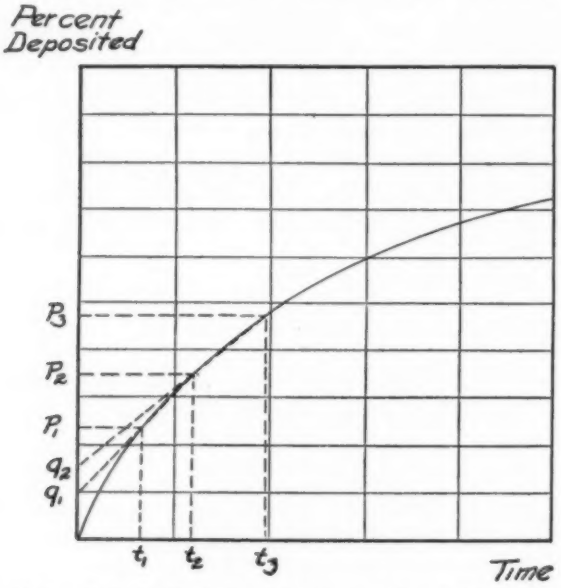

Fig. 1. Graphical method of Odén for resolving per cent deposited-time sedimentation curves. P_1 equals per cent of the material deposited at time t_1. q_1 equals per cent of the material having equivalent radii greater than that defined by t_1.

matical basis. His method for locating the point "q" which represents the quantity of particles of radii greater than that defined by the corresponding time "t" from the per cent deposited value "P" was as follows—

$$q_1 = P_2 - t_2\left(\frac{P_2 - P_1}{t_2 - t_1}\right). \qquad \text{(II)}$$

This formula is accurate for small increments of "t" and is independent of Stokes' Law. However, it is rather cumbersome.

A method for determining directly from the data the amount of particles of radii limited by the time function $(t_2 - t_1)$ would be much more useful. The rate of deposition of particles during the time interval $(t_2 - t_1)$ is $(P_2 - P_1/t_2 - t_1)$. During this time interval no particle larger than that defined by t_1 has been deposited. During the succeeding time interval $(t_3 - t_2)$ the rate of deposition is $(P_3 - P_2/t_3 - t_2)$ and during this time interval no particle larger than that defined

by t_2 has been deposited. Therefore, to get the rate of deposition of particles of radii defined by the time interval $(t_2 - t_1)$ one would have the difference between the rate during this time interval and the interval immediately succeeding it or $[(P_2 - P_1/t_2 - t_1) - (P_3 - P_2/t_3 - t_2)]$. The particles have been deposited at this rate during the maximum time of t_2 so the amount of such sized particles in the system is given by the equation

$$q_2 - q_1 = t_2\left(\frac{P_2 - P_1}{t_2 - t_1} - \frac{P_3 - P_2}{t_3 - t_2}\right). \qquad \text{(III)}$$

This equation is much simpler to apply than the equation of Knapp (II above) and gives the same results when applied to the same data.

An adaptation of Odén's weighing method for sedimentation analysis has been developed at the Minnesota Experiment Station. The medium for flour analysis was a mixture of carbon tetrachloride and cleaners' naphtha. The density of this mixture can be adjusted to any desired level. The viscosity of this mixture is reasonably constant through wide variations in composition and is low enough so as not to entrap air. However, it was found essential to determine density and viscosity of the mixture in use at the working temperature.

The apparatus developed for sedimentation analysis of flour is shown in Figure 2. An aluminum pan (A) 35 mm. in diameter was hung from the beam (B) of a chainomatic balance. The pan hung free inside a glass cylinder (C) 55 mm. in diameter and 100 mm. high supported by the bridge over the balance pan.

Method of Determination

The method of making a granulation determination upon a sample of flour is as follows:

The aluminum pan is dried and weighed in air, and then balanced with 200 cc. of the medium of known density and viscosity in the cylinder (C). The cylinder is then removed and the medium poured into a clean Erlenmeyer flask of 300 cc. capacity. A 5-gm. sample of flour is then placed in the flask, the flask stoppered and vigorously shaken for a minute until a smooth suspension forms. The suspension is quickly poured into the cylinder, the aluminum pan is put back in place, a stopwatch started and the increase in weight of the pan noted at frequent intervals. When practically all the flour has settled out, a 25 cc. aliquot of the supernatant liquid is pipetted into a tared moisture dish, and the aluminum pan carefully removed. The moisture dish and the pan are dried to constant weight in a moisture oven. The moisture content of the original flour must also be known or determined at this time.

After drying, the aluminum pan with the deposited flour is re-

weighed. When this weight is corrected for moisture loss in the oven it is possible to calculate the density of the flour. The weight of the residue of the supernatant liquid when corrected for moisture loss gives the amount of undeposited flour in the system. From this weight the per cent deposited at the last weighing can be directly obtained, and by similar calculations the per cent deposited at each observation time.

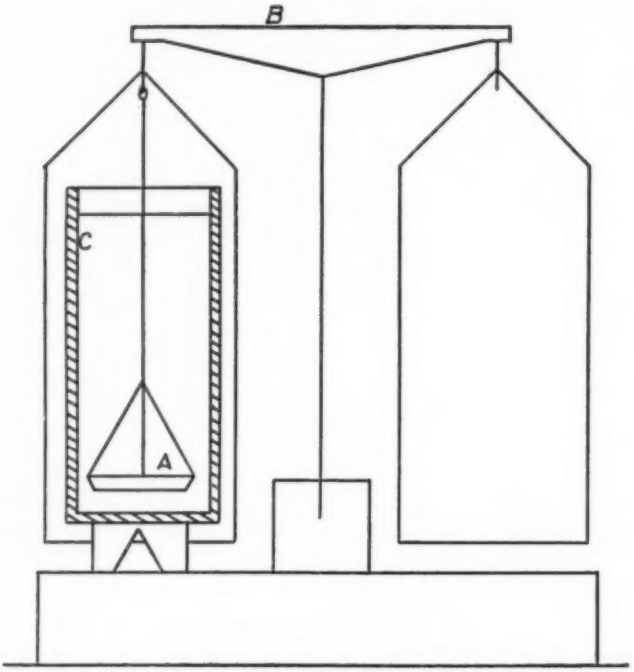

Fig. 2. Diagram of balance equipped for making sedimentation analyses. *A*—Aluminum pan suspended from balance beam. *B*—Beam of chemical balance (chain type). *C*—Cylinder holding suspension, supported by bridge.

The values obtained in this manner are then directly substituted into equations I and III and the size distribution for the flour under investigation determined.

In Figure 3 are shown per cent deposited-time curves for 5 flours. Flour A was a hard spring wheat patent flour of commercial origin. This flour was rebolted on an Allis bolter with a load light enough for all sieves to be showing bare spots within two minutes for one hour. This time was much longer than the usual time for making a granulation test, which is usually five to ten minutes. Flour B represented the fraction through a number 25XX silk. It is of interest to note that upon calculation the largest particles that were present in this flour in appreciable quantity had equivalent radii of 33.5 μ which was in close

agreement with the microscopic measurements of the openings of a 25XX silk bolting cloth as made by Gründer and by Van der Lee. Flour C was the fraction which passed through a 20XX silk but was retained upon a 25XX sieve. Upon calculation of the size distribution of this fraction it was found that the largest particles had radii of 39 μ, but also 68% of the stock had radii of less than 33.5 μ and consequently should have passed the 25XX silk if the bolting had been efficient.

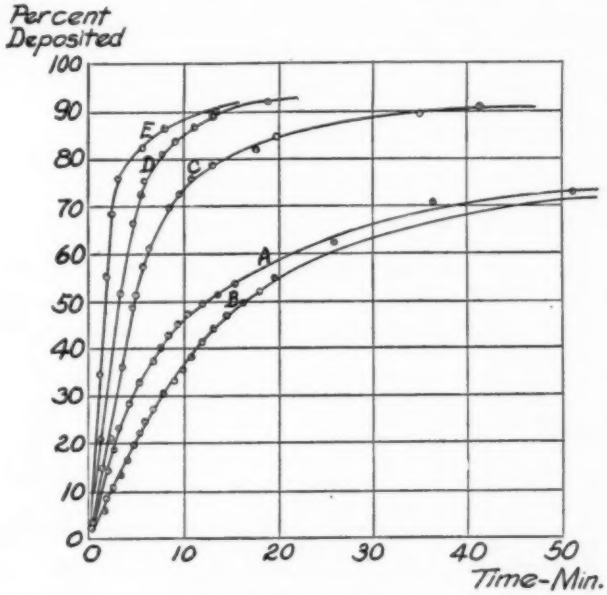

Fig. 3. Sedimentation curves of flours of different granulations. *A*—Commercial spring wheat patent flour. *B*—Portion of "*A*" passing 25XX silk. *C*—Portion of "*A*" passing 20XX and retained upon 25XX silk. *D*—Portion of "*A*" passing 16XX and retained upon 20XX silk. *E*—Portion of "*A*" retained upon 16XX silk.

Fraction D was that portion passing the 16XX silk and retained upon the 20XX silk. In this fraction the largest radii was 46 μ which is in good agreement with Van der Lee. This fraction was also inefficiently bolted since 44% of the material should have passed the 25XX silk. Fraction E was made up of the material which after an hour's bolting had failed to pass the 16XX silk. Even this coarse fraction was inefficiently bolted. In this case 26% of the material was found to be fine enough in granulation to pass a 25XX silk. Data for these flours are given in Table I.

These data indicate that at best sieving technic for the determination of particle size is inefficient, and that the sedimentation method offers some promise as a somewhat more accurate method. However, it should be kept in mind that sedimentation technic has certain disad-

TABLE I

DISTRIBUTION OF PARTICLES OF VARIOUS SIZES IN FLOURS OF VARYING GRANULATIONS

Flour	Equivalent radii—u								
	82.0–47.5u	47.5–38.0u	38.0–33.5u	33.5–24.5u	24.5–20.5u	20.5–18.5u	18.5–13.5u	13.5–11.0u	Smaller than 11.0u
A. Commercial Patent	0.5%	3.5%	9%	8%	11%	7%	3%	20%	38%
B. Through 25XX	0	0	0	9.5	6.5	5	...	...	... 79% smaller than 18.5u
C. Through 20XX over 25XX	0	0	16	26	22	3	...	...	... 33% smaller than 18.5u
D. Through 16XX over 20XX	0	11	32	21	15		...	...	... 21% smaller than 18.5u
E. Over 16XX	18	47	7	6	3	...	...	...	... 19% smaller than 20.5u

vantages, namely, being slow, and being unsuited for use with materials of varying densities or widely varying shapes of particles. For example, whole wheat flours would give erroneous results by this method.

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REPORT OF THE COMMITTEE ON TESTING BISCUIT AND CRACKER FLOURS

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(Presented at the Annual Meeting, June, 1934)

In a paper presented by the author at the joint session of the Cereal Chemists and Operative Millers at Chicago in 1933, biscuit and cracker flours were classed in three groups depending on strength:

Sponge type—strong, soft wheat flours.
Dough type (also for some cookies)—of intermediate strength.
Sweet goods (cooky) type—very weak flours.

The object of this committee was to devise tests or obtain interpretations of some of our present tests, which will identify a particular flour for type, and also indicate its quality and character for the type to which it belongs.

Without a preliminary discussion of the methods for determining strength and other characteristics of a flour, which would be out of place here, we may state that we have taken what are perhaps the most commonly used methods for determining these factors of flour for study this year—the baking test, and viscosity test.

Five flours, four of which were of known quality and characteristics (from commercial use) in biscuit and cracker production, were chosen for our work. Geographical and type descriptions of these flours (ash and protein on 15% H_2O basis) are as follows:

Flour 1. Ash—0.39%, protein—9.5%. A 90% Illinois-Indiana blend extremely popular for both cracker sponge and dough use. Lightly bleached, Agene.

Flour 2. Ash—0.41%, protein—9.7%. A standard patent western Missouri, unbleached. Widely used in cracker sponges. Might well be called a "strong sponge" flour.

Flour 3. Ash—0.41%, protein—8.8%. The "unknown" flour, from Missouri wheat. Chosen because the protein is high enough for a sponge flour, but the baking test indicated that it is too weak for that use. Unbleached.

Flour 4. Ash—0.40%, protein—7.2%. A Pacific "club," perhaps

the weakest U. S. soft wheat; widely used in vanilla wafers, hard sweets, and other fine cookies. Unbleached.

Flour 5. Ash—0.42%, protein—8.2%. An unbleached Pacific blend, largely Federation, widely used as a cracker dough flour.

A sample of each flour was sent to the members of the committee without any description or identification. Each member was asked to determine moisture, ash, and protein, and to make baking tests and run viscosities as described below. It is interesting to note that the ash results, calculated to the same moisture basis, fell within ± 0.01% of the averages which are the figures shown above. The protein results, calculated to the same moisture basis, fell within ± 0.2% of the averages as shown above. Such collaborative results are gratifying.

The methods which the committee members were asked to follow in making the viscosity readings and the baking tests were as follows:

Viscosity Determination

Weigh 20 gms. of flour on a triple beam balance. Transfer to a mortar and add 30 cc. distilled water. Rub flour into a smooth paste avoiding as much as possible a development of the gluten. After a smooth paste is obtained, gradually add more distilled water (25 cc. at a time) until a total of 100 cc. has been added. Transfer with stirring to cup of viscosimeter and make initial reading. Stop viscosimeter, add 1 cc. 1.0 N lactic acid and stir suspension thoroughly with bob and make another reading. Next add 2 cc. additional 1.0 N lactic acid, stir thoroughly and again read viscosity. Record readings taken after each acidulation until a total of 7 cc. has been added, the final reading being used as the viscosity of the flour. The intermediate readings taken are useful in judging the buffer value of the flour.

Run the viscosimeter at 14 r.p.m. and use a No. 30 phosphor bronze wire. Please report all the readings. If you use other than a MacMichael viscosimeter, please indicate which one and report your viscosity results.

Baking Test

The baking test will be the Werner method as given in Cereal Chemistry, Vol. 5, p. 158 (March 1928), with the following variations from the standard method.

Use a 2-hour fermentation with one punch only at 1 hour and 35 minutes.

Use 3 gms. of sugar instead of 2.5. In our laboratory we make 20 gms. salt and 60 gms. sugar to 1000 cc. 50 cc. of this solution carry the required amount of sugar and salt for 100 gms. of flour and contains 48 cc. of water.

Use an absorption of approximately 53% on a 13.5% moisture basis. The following absorptions for flours of various moisture contents will be close enough since the absorption is not critical.

Per cent moisture of flour	*Per cent absorption*
12.5 to 13.5	53
11.5 to 12.5	55
10.0 to 11.5	57

Bake a basic (minus) loaf; also one with 1 mgm. potassium bromate (called the plus loaf).

If you vary in any way from the method given, give this variation. For instance, we use the smallest Hobart mixer bowl and the paddle for mixing, using medium speed for 2 minutes. This gives a good mix without development, and

probably compares closely with hand mixing. Please describe your oven and use a rotary oven at 230° C. if possible.

Reporting the baking results will be difficult, but if we use the following terminology in describing the bread, it will be extremely interesting to see how close we can come to getting comparative results with each set of flours in the same laboratory and in different laboratories.

1. Ovenspring (expansion in oven)—large, medium, small.
2. Break—smooth, shell-top, torn, very ragged, none.
3. Crust color—dark, medium, pale.
4. Grain—very coarse, coarse, close and round, close and elongated. Color of crumb is unimportant and need have no consideration. The volume should be determined by the seed displacement method.

Since we are interested at least as much in comparing the results of the different members on each flour as in comparing the flours themselves, we shall take one flour at a time and give the results of the committee on that flour. The separate ash and protein results will not be given since the checks were so good, as mentioned above. The results, other than those given under viscosity, refer to the test loaves.

The laboratory reports on the five flours are shown in Tables I to V.

TABLE I

BAKING AND VISCOSITY TESTS ON FLOUR NO. 1

	Maximum viscosity	Volume, cc.	Ovenspring	Break	Crust color	Grain
Loaves without bromate						
R. M. Bohn	88	522	Large	Torn	Medium	Close; elongated
C. O. Oppen	100	425	Good	Smooth	Gold. brown	Elongated
W. V. Van Scoyk	92 [1]	445	F. small	Sl. ragged	Dark	F. round; sl. elong.
J. A. Dunn	100	465	Medium	Torn	Pale	Close
L. W. Haas	70 [2]	476	Large	Sl. shell	Medium	Close; elong.
G. Garnatz	102	378	Medium	Shell	Dark	Close; round
Loaves with 1 mgm. bromate						
R. M. Bohn	—	484	Medium	Torn; shell	Medium	Close; elong.
C. O. Oppen	—	460	Good	Smooth	Gold. brown	Elongated
W. V. Van Scoyk	—	435	F. small	Ragged	Dark	Sl. elong.
J. A. Dunn	—	435	Small	Ragged	Pale	Close
L. W. Haas	—	462	Large	Torn	Medium	Close; elong.
G. Garnatz	—	400	Medium	Shelled	Dark	Close; round

Remarks of collaborators: R. M. Bohn—very good strong sponge flour. C. O. Oppen—very strong; too strong for general sponge use. J. A. Dunn—should make a good cracker flour. G. Garnatz—strongest; shows indication of hard wheat; almost too strong even for cracker sponges.

[1] Mixed 20 gms. flour with 35 cc. water 1 minute with malted milk mixer; added balance water.
[2] Wallace & Tiernan viscosimeter.
F.—fairly; sl.—slightly; v.—very; elong.—elongated.

TABLE II

BAKING AND VISCOSITY TESTS ON FLOUR NO. 2

	Maximum viscosity	Volume, cc.	Oven-spring	Break	Crust color	Grain
Loaves without bromate						
R. M. Bohn	70	530	Large	Torn	Medium	Close; elong.
C. O. Oppen	83	460	V. good	Ragged	Gold. brown	Round
W. V. Van Scoyk	77 [1]	495	Large	Smooth	Dark	Coarse; round
J. A. Dunn	84	535	Large	Smooth	Pale	Close
L. W. Haas	54 [2]	504	Large	Shell	Pale	Close; round
G. Garnatz	77	443	Large	Smooth	Dark	Close; round
Loaves with 1 mgm. added bromate						
R. M. Bohn	—	545	V. large	Torn; shell	Medium	Close; elong.
C. O. Oppen		485	V. good	Ragged	Gold. brown	Round
W. V. Van Scoyk		490	Large	Smooth	Dark	Fine; round
J. A. Dunn		530	Large	Shell	Pale	Close
L. W. Haas		518	Large	Sl. shell	Pale	Close; elong.
G. Garnatz		475	Large	Smooth	Dark	Close; round

Remarks of collaborators: R. M. Bohn—very good strong sponge flour. C. O. Oppen—good sponge flour; the choice of No. 1 and No. 2. J. A. Dunn—good cracker sponge flour. G. Garnatz—a typical sponging flour.

[1, 2] See footnotes 1 and 2, Table I.

Discussion

Analytical Results (ash and protein)

As stated earlier, the checks on ash and protein of the seven collaborators was so close as to constitute good checks in the same laboratory.

Viscosity Determination

The checks on viscosity (excluding results obtained with the Wallace and Tiernan viscosimeter) were fair only among the various members of the Committee. It should be noted that the variations from one laboratory to another were fairly consistent. That is, each member showed about the same comparative differences among the various samples. It would seem that viscosity is worthy of further study and shows promise as a means of assaying flours for biscuit and cracker use. I might mention that recently in our laboratory we analyzed two flours which showed inadequate strength for sponge use by a baking test, yet gave a viscosity of about 60, which would definitely place them in the sponge

TABLE III

BAKING AND VISCOSITY TESTS ON FLOUR NO. 3

	Maximum viscosity	Volume, cc.	Oven-spring	Break	Crust color	Grain
Loaves without bromate						
R. M. Bohn	45	451	Little	Sl. torn	Sl. pale	Coarse; round
C. O. Oppen	55	399	Fair	Slight	Pale	Weak
W. V. Van Scoyk	51 [1]	440	Small	Smooth	Medium	Coarse
J. A. Dunn	50	445	Medium	Ragged	Pale	Coarse
L. W. Haas	33 [2]	420	Small	None	Pale	V. coarse
G. Garnatz	51	393	Small	Little	Quite dark	Sl. coarse
Loaves with 1 mgm. bromate						
R. M. Bohn	—	463	Little	Sl. torn	Pale	Sl. coarse; sl. elong.
C. O. Oppen		425	Fair	Slight	Pale	Weak
W. V. Van Scoyk		435	Small	Smooth	Medium	F. coarse; round
J. A. Dunn		440	Medium	Ragged	Pale	Coarse
L. W. Haas		406	Small	None	Pale	V. coarse
G. Garnatz		415	Small	Little	Medium	Sl. coarse

Remarks of collaborators: C. O. Oppen—nice cracker dough flour. J. A. Dunn—rather weak for crackers. G. Garnatz—suitable for cracker doughs and hard sweet goods.

[1], [2] See footnotes 1 and 2, Table I.

flour class. Unfortunately we have no information as to their utility for sponge purposes in commercial practice. It will be necessary to investigate such flours fully before it can be stated that viscosity is an infallible indication of the strength of flour for biscuit and cracker use. For the five flours studied, it may be said that the viscosity determinations placed the flours in the correct categories in practically every case.

Baking Test Results

The baking test gave very poor checks among the various laboratories. This is another indication that working out a "standard" baking test for flour testing is a difficult task, indeed, almost an impossible one. The comparative baking tests are particularly discouraging because it happens that the members of the committee are experienced in making baking tests by the A. A. C. C. method, and in most cases run them daily as a routine laboratory matter.

TABLE IV

BAKING AND VISCOSITY TESTS ON FLOUR NO. 4

	Maximum viscosity	Volume, cc.	Oven-spring	Break	Crust color	Grain
Loaves without bromate						
R. M. Bohn	30	442	None	None	Pale	Coarse; round
C. O. Oppen	38	415	Poor	Ragged	Pale	Coarse
W. V. Van Scoyk	41 [1]	435	Small	Smooth	Pale	V. coarse
J. A. Dunn	47	440	Medium	V. ragged	Pale	V. coarse
L. W. Haas	21 [2]	434	Small	None	Medium	Coarse
G. Garnatz	38	400	Small	Little	Pale	V. coarse
Loaves with 1 mgm. bromate						
R. M. Bohn	—	426	None	None	Pale	Coarse; round
C. O. Oppen		430	Good	Ragged	Pale	Coarse
W. V. Van Scoyk		450	Medium	Ragged	Pale	V. coarse
J. A. Dunn		425	Small	V. ragged	Pale	V. coarse
L. W. Haas		392	Small	None	Medium	V. coarse
G. Garnatz		408	Small	Little	Pale	V. coarse

Remarks of collaborators: C. O. Oppen—softest of the lot; good for a variety of purposes. W. Van Scoyk—No. 3 and No. 4 show perforated top crust. J. A. Dunn—good for vanilla wafers and other light pieces. G. Garnatz—a good cooky flour (this collaborator picked this as a Pacific Coast flour before its identity was known to him).

[1], [2] See footnotes 1 and 2, Table I.

In the same laboratory, however, there was no difficulty in getting comparative ratings for strength which not only checked the viscosity results but rated the flours correctly. It would seem that individually a chemist can work out a baking test with interpretations which will assay flours accurately for biscuit and cracker purposes. Perhaps the remarks of Mr. Garnatz sum up the situation neatly. "You will note that among these data we have classified the flours on the strength, and we desire to call your attention to the fact that the classification has been arrived at through observations of the results of the baking test without knowledge of the analyses or viscosities of the flours. You will note that our strength classification thus arrived at is in rather close agreement with the order in which the viscosity test would have arranged them, which brings up a point which we feel needs attention directed to it.

"Had we ranked the flours according to loaf volume, we should not

TABLE V

BAKING AND VISCOSITY TESTS ON FLOUR NO. 5

	Maximum viscosity	Volume, cc.	Ovenspring	Break	Crust color	Grain
Loaves without bromate						
R. M. Bohn	36	482	Medium	Sl. torn	Good	Coarse; round
C. O. Oppen	45	410	Slight	Slight	Gold. brown	Coarse
W. V. Van Scoyk	40 [1]	460	Small	Small	Dark	V. coarse
J. A. Dunn	44	460	Medium	Shell	Pale	Coarse
L. W. Haas	25 [2]	434	Small	None	Pale	V. coarse
G. Garnatz	43	393	Small	Little	Quite dark	Sl. coarse
Loaves with 1 mgm. bromate						
R. M. Bohn	—	478	Little	Smooth	Good	Coarse; round
C. O. Oppen		430	Slight	Slight	Gold. brown	Coarse
W. V. Van Scoyk		470	Medium	F. smooth	Dark	Coarse
J. A. Dunn		440	Small	Shell	Pale	V. coarse
L. W. Haas		406	Small	None	Pale	V. coarse
G. Garnatz		430	Small	Little	Quite dark	Sl. coarse

Remarks of collaborators: C. O. Oppen—very satisfactory cracker dough flour. J. A. Dunn—cookies such as hard sweets, etc. G. Garnatz—like No. 3; suitable for cracker doughs and hard sweets.

[1], [2] See footnotes 1 and 2, Table I.

have obtained a ranking that would have been in agreement with the viscosity tests. It is our feeling that in interpreting the results of the baking test, too much emphasis should not be given volume and more attention should be paid to some of the other characteristics of the loaf such as amount of ovenspring, nature of the break and shred, and character of texture and grain. We think this not only applies to soft wheat flours but to hard wheat flours as well."

With the remarks of Mr. Garnatz, the committee is in complete agreement. Since the factors mentioned as important by him are not susceptible to mathematical delineation or even to intelligible non-mathematical description, the working out of a baking test for adjudicating biscuit and cracker flours will not be easier than for bread flours.

L. W. Haas ran the flours through the Brabender farinograph, and furnished some preliminary information on this phase of the problem.

General Remarks and Recommendations

It is interesting to note that three members of the committee, J. A. Dunn, C. O. Oppen, and George Garnatz, all of whom have had considerable experience with biscuit and cracker flours, unerringly classified the flours correctly, both by viscosity and baking tests. They did this without knowledge of the source or commercial value of the flours. This would indicate that one or both of these tests are suitable for the assay of biscuit and cracker flours. Particular attention is called to flour No. 3 with 8.8% protein. This flour is high enough in protein for a sponge flour, but the three members mentioned had no difficulty in correctly characterizing it as too weak for sponge use.

It is recommended that a similar study, perhaps with some modifications, be continued over one or two more crop years at least before definite standard tests are set up for biscuit and cracker flours.

BOOK REVIEW

The Practice and Science of Breadmaking. By D. W. Kent-Jones. Published by The Northern Publishing Company, Ltd., 28 Paradise Street, Liverpool, 1, 1934. Price 7/6.

This is an elementary book dealing with the practice, but also emphasizing the scientific aspect, of breadmaking. It has been written to meet the demands for an elementary treatise and also to provide a textbook suitable for students, particularly those taking the examinations of the City and Guilds of London Institute in breadmaking. The twelve chapters cover the following topics: History and General Considerations of Breadmaking; Constituents of Flour; Types of Wheat and Milling; Dough Ingredients other than Flour; The Principles of Panary Fermentation; Breadmaking Processes; Bread Faults; Brown and Fancy Bread; The Nutritive Value of Bread; Bakery Machinery and Ovens; Bakehouse Management and Laws relating to the Baking Industry; Analytical Work.

Dr. Kent-Jones is recognized as an outstanding cereal chemist and is the author of "Modern Cereal Chemistry," which is a standard book on this subject. In his "Practice and Science of Breadmaking," while his discussions of fundamentals are necessarily brief, they are clearly stated and the book should be admirably adapted for the specific purpose for which it has been written. While the technical discussion of breadmaking is based on practices in the author's country, yet the scientific principles discussed throughout the book are such as to be of general interest and value. Wherever the information or advice is considered to be of special or outstanding importance, the printing is in heavy type.

F. L. DUNLAP

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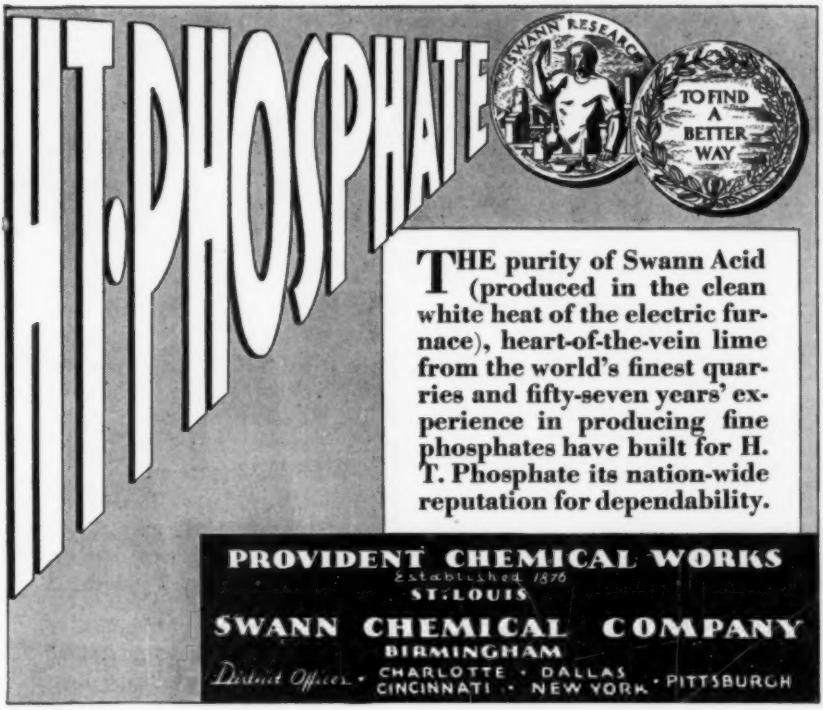
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